A METHOD OF ANATOMY

Descriptive and Deductive

BY

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PREFACE TO THE FOURTH EDITION

In this new edition the text has been revised throughout and many parts of it have been re-written; indeed, the pages on which no changes have been made are very few.

Bold type has been used more freely than formerly and headings and subheadings have been added widely throughout the text in the hope that they will make for more ready reference.

Sixty-eight new illustrations have been added, bringing the total number up to eight hundred, and sixty-seven old ones have been re-drawn, re-lettered, or otherwise improved.

The illustrations are the work of Miss Nancy Joy, to whom I express my appreciation of her artistic skill and of her willing co-operation. To my secretary, Miss Mary McConnell, my thanks are due for the care she has taken in checking references and in preparing the index. I do not forget to acknowledge the forbearance and consideration that the publishers, Messrs. Williams & Wilkins, so constantly show.

PREFACE TO THE FIRST EDITION

The study of human anatomy may be attempted in either of two ways. One consists in collecting facts and memorizing them. This demands a memory which is wax to receive impressions and marble to retain them. Even so endowed a student will not master the infinite complexities of the subject. The other way consists in correlating facts, that is, studying them in their mutual relationships. This leads inevitably to the apprehending of the underlying principles involved, and the "raison d'être" of such relationships. The student will thus learn to reason anatomically and will find the acquisition of new and related facts an easier task. It is the purpose of this book to lead the student to approach the subject from this viewpoint, and it involves certain departures from tradition.

The human body is here considered by regions. In most regions some feature predominates. It may be a muscle, a vessel, a nerve, a bony landmark or other palpable structure or it may be a viscus. The regions are for the most part built up around the dominant or central feature.

The markings, lines and ridges, depressions and excrescences, on a bone tell a story as do the scars and irregularities on the earth's surface. Because they are in the main to be interpreted by reference to the soft parts that surround and find attachment to them, the bones are not described together under the heading "osteology" as though they were things apart. The shafts of the bones are considered with the surrounding soft parts; the ends with the joints into which they enter. The bones of the foot are primarily considered as a single mechanism—so are those of the hand and of the skull. The correct orientation of certain bones is given in cases where without this information the actions of certain muscles (e.g. Gluteus Medius, Teres Major) could not be understood.

It is not the mere presence of a ligament or its name that is of interest, but the functions it serves. These depend commonly on the direction of the fibers of the ligament; occasionally on their precise attachments. Many fibrous bands bearing individual names are really members of a community. A challenge thrown at one must be taken up by all. They act in unison and therefore they are considered together as a unit.

In the consideration of viscera the subject is elucidated by reference to comparative anatomy and to embryology. These are cognate sciences which throw light about the existing structure of man. The positions of the viscera are referred to selected vertebral levels, the vertebral column being an ever present and ever ready measuring rod.

Surface Anatomy is largely dispensed with as an independent subject. Its study is undertaken as a review of Gross Anatomy, distances being measured, wherever feasible, in terms of structures. For example, instead of stating that the posterior tibial artery lies half an inch from the tibial malleolus—which would be a new fact to memorize—it is spoken of as being the breadth of two tendons from the malleolus, the tendons being the tibialis posterior and flexor digitorum muscles—a fact already

learned by dissection. Again, by regarding the left renal vein as the vein of the three left paired abdominal glands (adrenal, renal and sex) its length is easily calculated as being the length of the right renal vein, plus the width of the vanished left inferior vena cava, plus the breadth of the aorta, say $1\frac{1}{2} + 1 + 1 = 3\frac{1}{2}$ inches. And, again, the memory is not strained to recollect that the adrenal gland lies at the level of the twelfth thoracic vertebra when the fact can profitably and readily be deduced from a series of related circumstances.

Illustrations to be of value must be simple, accurate, and convey a definite idea. It is for these reasons that they consist entirely of line drawings. Their simplicity encourages the student to reproduce them; and though diagrammatic in nature they are based on measurements and observations of a great deal of carefully dissected material. Their accuracy therefore, in those details they are intended to illuminate, has been the object of very considerable work. Many of the original dissections are to be found in the anatomy museum of the University of Toronto. In many instances the names of the structures in the illustrations have with care been grouped to form tables which are complete in themselves, as in figures 132 and 577. It is hoped that this tabular arrangement will add to the usefulness of the illustrations.

With few exceptions The Birmingham Revision (B. R.) of the B. N. A. terminology is employed in this book. Such synonymous and alternative terms as differ considerably from the B. R. terms, and such as are likely to die hard, are recorded within brackets in the text immediately after the B. R. terms.

The book is meant to be a working instrument designed to make Anatomy rational, interesting and of direct application to the problems of medicine and surgery. The bare, dry and unrelated facts of Anatomy tend rapidly to disappear into forgetfulness. That is largely because its guiding principles are not grasped so as to capture the imagination. Once they are grasped it will be found that details and relationships will remain within certain and easy recall.

I am indebted to many of my friends and colleagues for the help they have given me in this plan and I take this opportunity of expressing to them my very grateful thanks. I mention in particular: Dr. Brock Brown, who has so willingly and ably assisted with most of the illustrations and therein has displayed his artistic skill; Mr. J. G. Watt, who has so successfully executed the illustrations on the thorax; Mr. E. M. Davidson, whose experienced pencil laid the foundation of many of the figures; Dr. J. C. Watt and Dr. H. A. Cates, who have read many sections of the manuscript and have offered valuable criticisms; Dr. C. G. Smith and Mr. H. C. Elliott, who have read the entire proofs with great care; Dr. R. K. George, who has prepared the index; Dr. B. L. Guyatt, who has made many dissections and has helped to verify the innumerable points on which the figures are based; and Mr. H. E. LeMasurier, who has rendered many diverse and valuable services.

J. C. BOILEAU GRANT.

INTRODUCTION

There are few words with a longer history than the word Anatomy. If we write anatome we use the name that Aristotle gave to the Science of Anatomy two thousand three hundred years ago. He made the first approach to accurate knowledge of the subject, although it was derived from dissections of the lower animals only. The word means cutting up—the method by which the study of the structure of living things is made possible.

The boundaries of the subject have widened. Through the use of the microscope and with the aid of stains the field of Anatomy has come to include microscopical anatomy or *histology* and the study of development before birth or *embryology*. The study of the anatomy of other animals, *comparative anatomy*, has been pursued exhaustively partly in an endeavor to explain the changes in form, *morphology*, of different animals including man. *Physical Anthropology*, or the branch of the study of mankind that deals chiefly with the external features and the measurements of different races and groups of people, and with the study of prehistoric remains commands interest of the anatomist. The hereditary, nutritional, chemical, and other factors controlling and modifying the growth of the embryo, of the child, and of animals are within his legitimate field; so also is the growth of tissues in test-tubes, *tissue culture*. Feeding and other experiments on animals play leading parts in many investigations.

Individuals differ in outward form and features; for example, how varied are finger prints and the arrangement of the veins visible through the skin: individuals differ also in their internal make-up. Textbooks, for the most part, describe average conditions where weights and measures are concerned, and the commonest conditions where arrangements and patterns are concerned. Owing to the variety of these the commonest may have less than a 50 per cent incidence—it may, therefore, not be truly representative. As data on variations accumulate the subject of *Statistical Anatomy* emerges. Some variations are so rare as to be abnormalities or *anomalies*. Among the different races of mankind there are percentage differences in the form and arrangement of structures, just as there are among the different races of the apes and other animals. But relatively little is known as yet of *Racial Anatomy*, which is a branch of physical anthropology.

The human body is generally dissected by regions, *Regional Anatomy*, and described by systems, *Systematic Anatomy*. The regions of the body comprise: The head and neck, the trunk, and the limbs. These can be divided and subdivided indefinitely. The trunk is divisible into thorax, abdomen and pelvis. The systems of the body comprise the skeleton, the study of which is osteology; the joints (arthrology); the muscles (myology); the nervous system (neurology), which includes the brain, spinal cord, organs of special sense, the nerves, and the autonomic nervous system: the cardio-vascular system which includes the heart, blood vessels, and lymph vessels. The viscera of the body, (exclusive of the heart and parts of the nervous system),

comprise four tubular systems,—the digestive, respiratory, urinary, and genital—and the ductless or endocrine glands. All these are wrapped up in the skin and subcutaneous tissue.

Anatomy considered with special reference to its medical and surgical bearing is called *Applied Anatomy*. Anatomy can be studied profitably, though to a limited extent, by means of cross-sections, *Cross-Section Anatomy*. In the living subject a great deal can be learned by inspection and palpation of surface parts. This and the relating of deeper parts to the skin surface, *Surface Anatomy*, are a necessary part of a medical education. And, the X-ray reveals much that cannot be investigated by other means.

DESCRIPTIVE TERMS

In describing the relationship of one structure to another it is obviously highly necessary—if we would have our description understood—that we employ certain accepted terms. Only by so doing can we avoid ambiguity and misunderstanding.

For descriptive purposes the human body is regarded as standing erect, the eyes looking forwards to the horizon, the arms by the sides, and the palms of the hands and the toes directed forwards: this is the *Anatomical Position*. The cadaver may be placed on the table lying on its back, on its side, or on its face, but for descriptive purposes it is assumed to be standing erect in the Anatomical Position. The palms of the hands can be made to face any direction: resting on the table they face downwards (inferiorly); turn them round and they face upwards (superiorly); as they hang by the sides they may face each other (medially), away from each other (laterally), backwards (posteriorly), or forwards (anteriorly). One of these positions, namely, the forward facing one, is by convention selected as the anatomical one—despite the fact that it is not the most comfortable. That is to say, the palm of the hand is understood to be the anterior surface of the hand and it is not permissible to refer to it variously as the posterior, inferior, superior, medial, or lateral surface according to passing fancy or because it happens temporarily to face one of these directions. From these remarks it should be evident that to misapply terms of relationship is to court confusion.

The body is divided into two halves, a right and a left, by the *median* or *midsagittal plane*. The anterior and posterior borders of this plane reach the skin surface at the front and back of the body at the *median* or *mid line*

Three pairs of relative terms suffice to express the relationship of any given structure to another (*fig. 2*). They are:

Anterior or in front = nearer the front surface of the body.
Posterior or behind = nearer the back surface of the body.
Superior or above = nearer the crown of the head.
Inferior or below = nearer the soles of the feet.
Medial = nearer the median plane of the body.
Lateral = farther from the median plane of the body.

The foregoing terms are applicable to all regions and all parts of the body—always provided that the body is, or is assumed to be, in the anatomical position.

When it is desired to compare the relationship of some structure in man with the same structure in say a dog, it is necessary to use a different set of terms, terms related not to space but to parts of the body, such as the head, tail, belly, and back. For example: in man standing erect the heart lies above the diaphragm; in the dog standing on all fours it lies in front of the diaphragm; but in both instances its position relative to other parts of the body is the same; so, *speaking comparatively*, one would say that both in man and in the dog the heart is on the head, cranial, or cephalic side of the diaphragm (*fig. 3*).

Hence, the terms *ventral* and *dorsal*, *cranial* and *caudal*, as well as *medial* and *lateral* are applicable to the trunk or torso (thorax, abdomen, and pelvis) irrespective of the position assumed by the body. Moreover, it is desirable to employ these terms in embryology and comparative embryology; and it is quite correct to employ them in human anatomy for no misunderstanding can arise from their use as synonyms for anterior, posterior, superior, and inferior.

In the limbs, terms are coupled with reference to (a) the proximity to the trunk—*proximal* = nearer the trunk, and is synonymous with superior; *distal* = farther from the trunk, and is synonymous with inferior, (b) the morphological borders—*preaxial* = the lateral or radial border (i e, thumb side) of the upper limb, and the

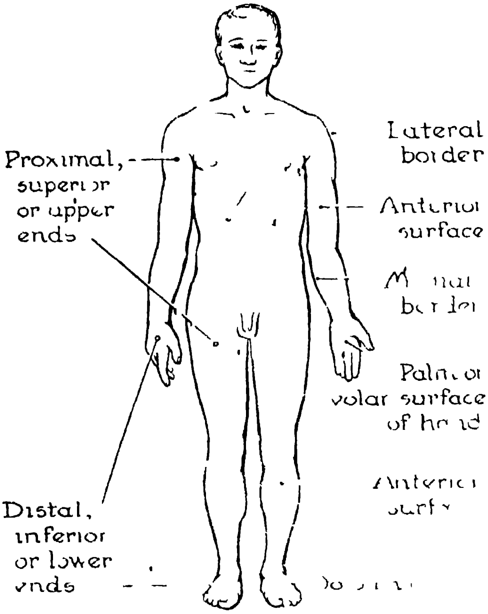

FIG. 1. The subject is in the Anatomical Position—except for the right forearm which is pronated

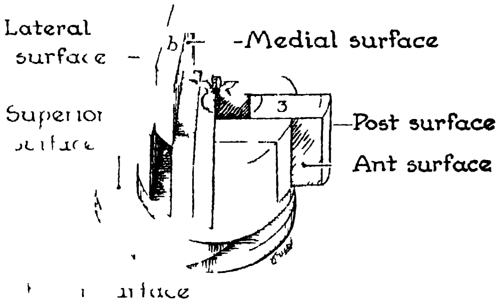

FIG. 2 Three pairs of surfaces involving six essential descriptive terms They are related to the three fundamental planes in the body

medial or tibial border (i e , big toe side) of the lower limb, *postaxial* = the medial or ulnar border of the upper limb, and the lateral or fibular border of the lower limb; and (c) the functional surfaces—*flexor* and *extensor*, the flexor surface being anterior in the upper limb and posterior in the lower limb

The anterior surface of the hand is generally called the *palmar* (or volar) surface, and the inferior surface of the foot the *plantar* surface The opposite surfaces are called the *dorsum* of the hand and foot

OTHER TERMS: *Inside* or *interior*, and *outside* or *exterior* are reserved (a) for bony cavities, such as the pelvic, thoracic, cranial, and orbital, and (b) for hollow organs, such as the heart, mouth, bladder, and intestine (*fig 4*)

An *invagination* and an *evagination* (L. vagina, = a sheath or scabbard) are inward and outward bulgings of the wall of a cavity.

Superficial and *deep* denote nearness to and remoteness from the skin surface.

On, *over*, and *under* are terms to beware of. They should be used in a general sense and without specific regard to the anatomical position. Just as a fly may be *on* the ceiling, wall, or floor, so a tubercle may be *on* any part of a bone, and a sulcus may be *on* any surface of the brain. A vessel may pass *under* or *over* an arch or bridge; and a

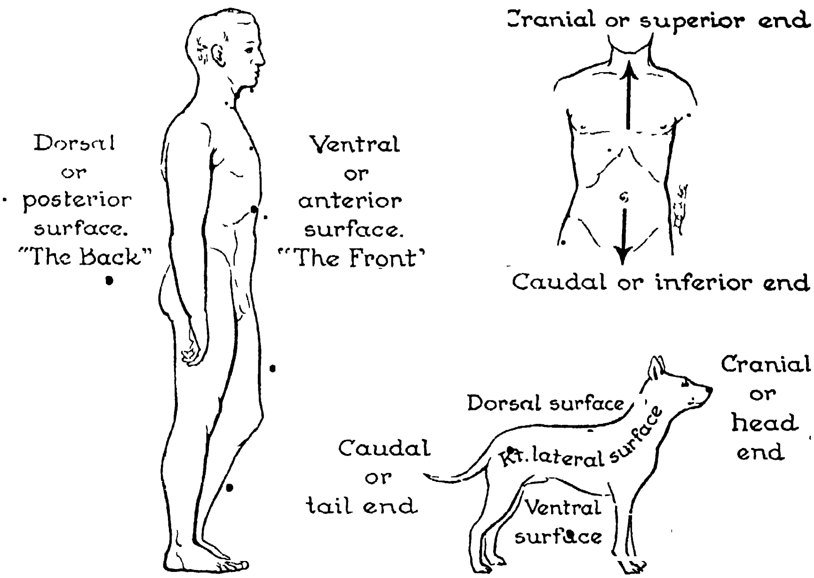

FIG. 3. Three pairs of terms necessary to comparative anatomy and of more general application than those given in figure 2.

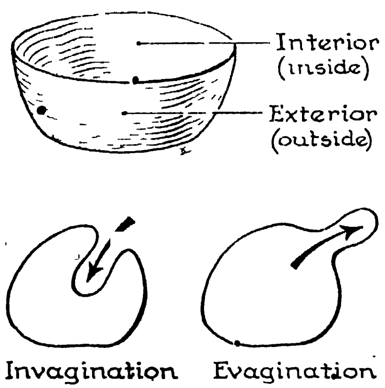

FIG. 4. Four descriptive terms.

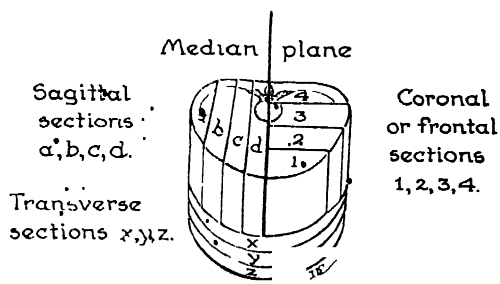

FIG. 5. The three fundamental planes in the body.

nerve may lie *under* the deep fascia. Used in these senses the terms are explicit. Carefully avoid using them loosely in place of "superior to" and "inferior to," for such misuse is the cause of much misunderstanding.

In relation to (related to) is not an informative term unless it is specified what the relationship is, e.g., close, intimate, remote, occasional.

PLANES: (1) *A sagittal plane* is any vertical antero-posterior plane, including the

median plane. It is parallel to the sagittal suture of the skull. (2) *A coronal* or *frontal plane* is any vertical side-to-side plane at right angles to the sagittal plane. It is approximately parallel to the coronal suture of the skull. (3) *A transverse plane* is any plane at right angles to 1 and 2, i.e., at right angles to the long axis of the body or limb. In the case of an organ or other structure a transverse plane or a *cross section* is a plane or section at right angles to the long axis of that organ or structure. (4) *An oblique plane* may lie at any angle.

Muscle attachments. Muscles are attached at both ends. The proximal attachment of a limb muscle is its *origin*; the distal end is its *insertion*.

Note. It would be logical to regard the fixed end as the origin and the moving end as the insertion, if they were constant; but they are not constant, they are reversible. Thus, when pulling on an oar, the Latissimus Dorsi draws the humerus backwards, towards the body; but when climbing a tree, it draws the body forwards, towards the humerus. Similar examples are numerous in the lower limb due to the

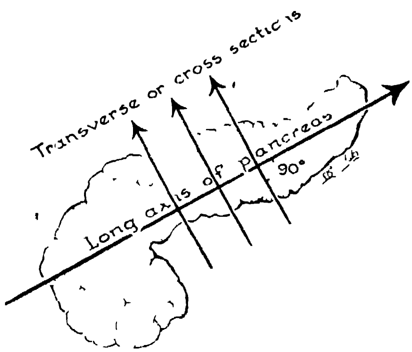

Fig. 6. A cross section of an organ or part is a section made at right angles to its long axis.

fact that in walking the right foot is stationary on the ground while the left foot is advancing; and this condition is reversed when the next step is taken. Hence, the origins and insertions of the lower limb muscles are alternately fixed and moving.

Vessels. Arteries are likened to trees with branches; veins are likened to rivers with tributaries. Before Harvey discovered that blood moved "in a circle" both arteries and veins were spoken of as having branches, and there is no objection to-day to referring to the branch of a vein.

Movements at Joints. *To flex* is to bend or to make an angle.

To extend is to stretch out or to straighten. Movements of flexion and extension take place at the elbow joint.

To abduct is to draw away laterally from the median plane of the body.

To adduct is the opposite movement in the same plane (L. ab = from; ad = to; duco = I lead). Movements of abduction and adduction, as well as of flexion and extension, take place at the wrist joint.

The middle finger is regarded as lying in the *axial line of the hand*; and the 2nd toe as lying in the *axial line of the foot*. Abduction and adduction of the fingers and toes are movements from and towards these axial lines. The thumb movements are named differently, see page 140.

To circumduct (L. circum = around) is to perform the movements of flexion, abduction, extension, adduction, and flexion in sequence, thereby describing a cone, as can be done at the shoulder, hip, wrist, and metacarpo-phalangeal joints.

To rotate is to turn or revolve on a long axis, as—the arm at the shoulder joint, the femur at the hip joint, the radius on the ulna, and certain vertebrae on each other.

To pronate was originally to bend or flex the body forwards as in obeisance in prayer, that is face downwards or prone. Applied to the forearm it means to turn it so that the palm of the hand faces downwards on a table, which is the equivalent of facing backwards when it hangs by the side. Pronation is, therefore, a movement of medial rotation.

To supinate is to rotate the forearm laterally so that the dorsum of the hand rests on the table or faces backwards when the limb hangs by the side. Supine = lying on the back.

To protract (L. pro = forwards; traho = I pull) is to move forwards.

To retract is to move backwards. Protraction and retraction are terms applied to the movements of the jaw and shoulder girdle.

For every reason the student should from the first use, use only, and use correctly the accepted terms.

ADVICE TO THE DISSECTOR

Though not a dissector's guide, this manual is for use in the laboratory and museum where dissected material is available and some advice to the dissector is ventured.

Wear a long white coat as a protection to your clothes, and keep your nails short.

MATERIAL. You, the dissector, will appreciate the privilege accorded you of being able to study human material and your natural instincts will lead you to treat it with the respect due to the dead.

Before you assume responsibility for the cadaver it has been embalmed with *antiseptics* (probably including carbolic acid), *hardening fluids* (probably spirit and formalin), *hygroscopic agents* (probably glycerine and potassium acetate), and *salts;* the arteries have been filled with a colored mass (probably starch, red lead, and glue) to render them conspicuous. Take intelligent steps to keep the parts allotted for dissection firm and moist but not sodden, because a part that has been allowed to dry cannot be restored to its former state. Keep the part surrounded with cotton waste, which is soaked in lotion (e.g., saline solution containing an antiseptic, glycerine, and spirit, with formalin as required) and held in place with a bandage; and envelope it in a waterproof sleeve open at one end like a pillow-case. Never expose even for half-an-hour more of a part than necessary. For example, keep the forearm and hand properly covered while investigating the axilla and arm, and keep moistened cotton waste in the axilla and about the arm while investigating the forearm and hand. Unwrap and examine the covered parts periodically (every week or two at the start) and moisten if necessary; pour fluid into the nose and mouth; and pay special attention to the hands, feet, nose, scalp, and external genital organs which dry readily. Ignoring holes in the waterproof sack and letting the ends of cloths project beyond the mouth of the sack, so that they act as wicks promoting loss of fluid, is not acting intelligently. Lotion injected hypodermically followed by massage will partially refresh neglected parts. Water is apt to cause mould to grow. Swabbing with carbolic acid and glycerine destroys mould. It is convenient to have at hand a round, 10–12 ounce bottle of lotion fitted with a sprinkler such as laundry maids use.

INSTRUMENTS. Required are a pair of forceps, a seeker, scissors, two knives, and a stone. The *forceps* should be 4½–5 inches long with handles transversely ridged to prevent slipping, ends blunt and rounded, and gripping surfaces ridged and furrowed. A *seeker*, that is a rigid 5 inch steel probe with bent tip, is required for seeking for nerves and vessels in areolar tissue and fat. The finger makes a useful explorer. The *scissors* should be about 5 inches long, preferably with the tip of one blade sharp and the other blunt. *Knives:* Two knives are required. One is for rough work such as cutting skin and tendons. The handle of this knife, if squared at the end so as to have two edges like the end of a microscope slide, can be used for scraping periosteum and fascia from bone and thereby displaying the attachments of tendons and ligaments. The other knife is for the more delicate work, for cleaning vessels, nerves and the like. The handle of this knife, if smooth and rounded at the end, can

be used as a separator or blunt dissector. If the handle of the knife slips in your grasp, winding around it a few turns of thread or adhesive tape will afford a friction surface, or a length of rubber tubing may be slipped over the handle. The blade should be $1\frac{1}{2}$ inches long and narrow throughout. Some convexity is necessary because, in dissecting, the blade usually precedes the handle and in this position a straight edge tends to hook up the tissues. The convexity should however be slight, and the point should be well tapered rather than well rounded. In dissecting, the terminal 3 to 5 mm. of the blade are used almost exclusively. A full bellied edge therefore is excess metal to be worn away on the grindstone.

A good blade is made thin (except at the back) by being hollow-ground. This enables it to be sharpened readily. Its rigidity depends upon the thickness of its back. Detachable blades are very thin throughout. A thick blade requires frequent grinding. While in use the end 3 to 5 mm. should retain the sharpness of a razor. For this a few strokes on the sharpening stone are required many times a day. Make incisions with the belly of the blade; dissect with the end 5 mm.; sever with the heel any tough tissues that would blunt the cutting edge. *The sharpening stone* should be flat, hard, and of fine texture (carborundum is satisfactory). Soap lather may be used for lubricating. Everyone who possesses a knife should also possess a sharpening stone.

SHARPENING THE KNIFE. Viewed under the microscope the margin of a well sharpened blade is ruled with parallel lines to the depth of 1 mm. and the very edge is finely notched, somewhat like a saw. Such an edge cuts with less pressure than a perfectly smooth one. The aim therefore in sharpening a knife is to direct the stroke so as to produce such an edge. The sharpening is best done by making ten strokes alternately on one side of the blade and then on the other, using light pressure. The edge requires to be ground to the depth of 1 mm. only, so by raising the back of the blade just clear of the stone unnecessary grinding can be avoided. The cutting edge should move forwards at an angle of 60°. If the blade were straight the movement would be a simple one, but the blade has a belly and a point. It is especially necessary to maintain an angle of 60° when the belly and point are in contact with the stone and in order to do so *a curve must be described which is identical with the curve of the blade (figs. 7, 8, 9).*

When the knife is very dull and considerable grinding is necessary, stroke the blade along the stone, edge leading, because the "wire edge" formed in the process is more readily brushed away than when the edge follows. Continue the grinding until the dull areas and notches are completely worn away. Light pressure only is required. The procedure is as follows: the heel of the blade is applied to the right hand end of the stone, position 1, with the edge making contact at an angle of 60°, and the back of the knife raised free from the stone. The knife is drawn forward and toward the operator.

When the curved portion of the blade is advancing in contact with the stone the guiding hand makes a sweeping movement—describes an arc—thereby maintaining contact at 60°. At the same time the handle as well as the back of the blade is made to rise progressively in order that the margin shall be ground to the same depth (1 mm.) throughout.

The stroke is not completed until the very tip of the blade has made contact Each stroke is made in exactly the same fashion.

The sharpening is best completed by making about five strokes on one side and then five on the other, using very light pressure and with the back now leading and the edge following. The procedure would be illustrated by figure 3 by reversing the direction of the arrows. It will be observed that the direction of the lines on the blade is not altered thereby. With reference to the foregoing description this might be termed the return stroke.

Care must be taken not to leave the tip unsharpened. Students frequently present blades which are unsatisfactory though "sharpened". In these cases the microscope reveals the last 1 or 2 mm. to have made no contact with the stone. Stropping is not necessary: very delicate work can be undertaken successfully without the aid of a strop. (The foregoing description is by Dr B. L. Guyatt.)

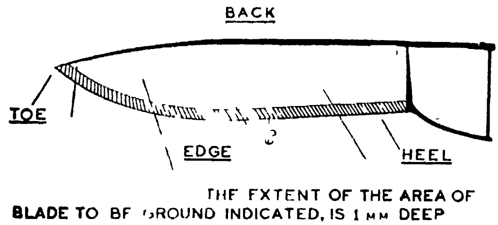

FIG. 7

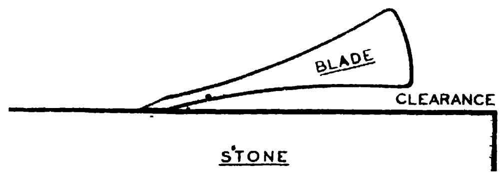

FIG. 8

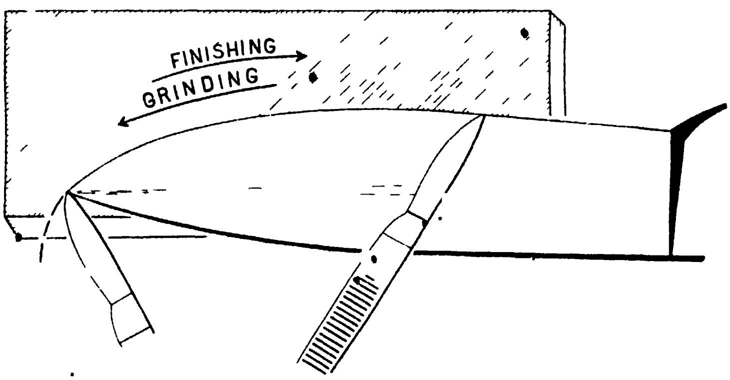

FIG. 9 The excursion of the blade should describe the outline of the blade

DISSECTION. In dissecting the rule is to begin by locating the important structures and those in danger of damage. Nerves are, for the most part, more important than vessels; motor nerves than sensory nerves; arteries than veins. Where there are so many veins that "the wood cannot be seen for the trees", let all but the chief ones go, thereby saving time and obtaining a clearer picture; e.g., in the axilla keep the axillary and cephalic veins; in the femoral triangle the femoral, profunda femoris, and long saphenous veins. If an important artery has been destroyed, save its companion vein as a substitute. Cutaneous veins are usually superficial to cutaneous nerves. Cutaneous nerves commonly pierce the deep fascia accompanied by arteries, which if well injected serve as guides to the less conspicuous nerves. Every dissection should, so to speak, be set in a frame composed of significant local structures—

such as the borders of muscles, main arteries, and bones—from which one can get one's bearings. After the contents of the frame have been identified, the areolar tissue and fat should be removed from the muscles, and the vessels and nerves should be cleaned with the knife and by drawing the gripping surfaces of the forceps along them. A clean dissection in its frame impresses the eye. The dissection should be ended by defining the bony attachments of the tendons; doing so at the end of a dissection takes no time; it immensely improves ones knowledge of the bones; and it reveals the direction of the pull of the muscles and perhaps their actions. The same apply to ligaments. Muscles being important as landmarks should never be divided without very good reasons.

It is waste of time to clean unidentified structures.

Where two are working on the same part, one should spend some of his time reading, examining other specimens, in the museum, or in preparing himself for his turn at dissection. The thoughts behind the knife count more than the mechanical process of dissecting.

As a routine the last 5–15 minutes of each dissection period should be spent in naming and handling structures, in restoring relations that have been disturbed, and in reviewing the work of the day.

SECTION I

GENERAL

CHAPTER 1

This section deals, in a general way, with the systems of the body. However, certain lists of items and some details of structure, nerve supply, and blood supply are included for the convenience of the more advanced student. The beginner should pass them over lightly.

BONE AND CARTILAGE

A bone of a living man is itself a living thing. It has blood vessels, lymph vessels, and nerves. It grows. It is subject to disease. When fractured it heals itself; and if the fracture is so improperly set that the parts have lost their previous alignment, its internal structure undergoes remodelling in order that it may continue to withstand strains and stresses as it did before. Unnecessary bone is resorbed: for example, following the extraction of a tooth, the walls of the socket, thus rendered empty, disappear; also, the bones of a paralysed limb atrophy (become thinner and weaker) from disuse. Conversely, when bones have increased weight to support they hypertrophy (become thicker and stronger).

Bones have an *organic framework* of fibrous tissue and cells, amongst which *inorganic salts*—notably, phosphate of calcium—are deposited in a characteristic fashion. The fibrous tissue gives the bones resilience and toughness; the salts give them hardness and rigidity and make them opaque to X-rays. One third is organic; two thirds are inorganic.

Physical Properties. By submerging a bone in a mineral acid the salts are removed, but the organic material remains and, still displays in detail the shape of the untreated bone. Such a specimen is flexible: for example, a decalcified fibula can be tied in a knot (*fig. 10*); when the knot is untied the fibula springs back into shape.

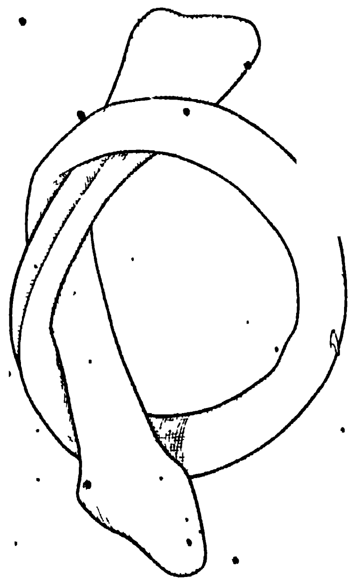

FIG. 10. A decalcified fibula can be tied in a knot.

The organic material of a bone, long buried near the surface of the earth, is removed by bacterial action (i.e., decomposition) and only the salts remain. The same result can be achieved more speedily by burning with fire. A bone so-treated, being more brittle than porcelain, will break unless handled with care. Bones that have lain buried in a

limestone cave become petrified (i.e., calcium carbonate replaces the organic material); so, they endure; so do those that are mineralised through lying in soils containing, say iron, lead or zinc. Moisture being necessary to bacterial action, bones that have remained thoroughly dry (mummified) retain their organic framework and therefore much of their toughness. The anthropologist about to exhume fragile bones first toughens them by "petrifying" artificially,

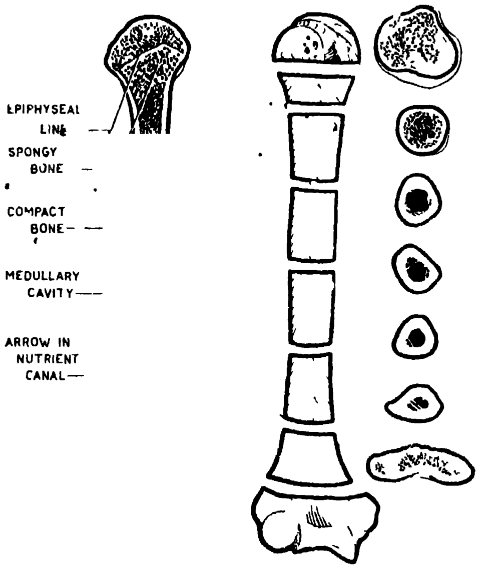

FIG. 11. The structure of a dried bone as shown by longitudinal and transverse sections of a humerus.

by impregnating them with shellac dissolved in spirit or with cellulose dissolved in acetone.

Functions of Bones. In addition to being (1) the rigid supporting framework of the body, bones serve as (2) levers for muscles; (3) they afford protection to certain viscera (e.g., brain and spinal cord, heart and lungs, liver and bladder); (4) they contain marrow, which is the factory for blood cells; and (5) they are the storehouses of calcium and phosphorus.

Structure of a dried bone seen on section (*fig. 11*). MACROSCOPICALLY, there are two forms of bony tissue (a) *spongy* or cancellous and (b) *compact* or dense.

All bones have a complete outer casing of compact bone; the interior is filled with spongy bone except where replaced by a medullary cavity or an air sinus (see below). In a long bone, such as the humerus, the compact bone is thickest near the middle of the shaft and it becomes progressively thinner as the bone expands towards its articular ends, these being covered by a mere shell of compact bone. Conversely, spongy bone fills the expanded ends and extends for a variable distance along the shaft but leaves a tubular space, the *medullary cavity*. The *lamellae* or plates of the spongework are arranged in lines of pressure and of tension, and in an X-ray photograph the pressure lines are seen to pass across joints from bone to bone (*fig. 168* of the hip joint).

Classification. The bones of the body may be classified variously:

(1) DEVELOPMENTALLY: according to whether they developed (a) in cartilage or (b) in membrane.

(2) REGIONALLY.

Axial Bones	Skull	cranium, face	22
		auditory ossicles	6
		hyoid	1
	Vertebrae		26
	Ribs		24
	Sternum		1
Appendicular Bones	Upper limb	Pectoral girdle, Free bones	64
	Lower limb	Pelvic girdle, Free bones	62
			206

This number is not exact. It varies with age and with the individual, being larger

in youth while the individual parts of compound bones (e.g., frontal, sacrum) are still discrete and when accessory or supernumerary bones are present, and being smaller when two bones have fused (e.g., fusion of lunate and triquetrum, or of two vertebrae) and when a bone is suppressed or congenitally absent (e.g., absent phalanx or vertebra).

(3) ACCORDING TO SHAPE:

(1) Long } peculiar to the limbs.
(2) Short }
(3) Flat } peculiar to the axial
(4) Irregular } skeleton and the girdles.
(5) Sesamoid—in certain tendons.

LONG BONES are tubular. They are confined to the limbs, where they serve as levers for muscles. By their length they increase the reach of the upper limb and the stride of the lower limb. Primitively, all long bones are weight-bearing.

A long bone has a shaft (body) and two ends. The *ends*, being articular, are smooth, covered with cartilage, either convex or concave, and enlarged. This enlargement increases the bearing surface and diminishes the risk of dislocation. The *shaft* is hollow (medullary cavity) as a straw is hollow, thus obtaining most strength with least expenditure of material and with least weight. It, typically, has three borders which separate three surfaces, so on cross-section it is triangular rather than circular. The borders may be likened to 3 pieces of unbendable angle-iron; 3 surfaces connect the 3 unbendable borders (*fig. 12*). The three surfaces and borders are named by opposites, see pages 126, 416. The shaft is thinnest near its middle and it expands gradually towards each end. Long bones develop (are preformed) in cartilage. The shaft of every long bone begins to ossify (primary centre) about the 2nd to 3rd foetal month. One or both ends begin to ossify (secondary centres) subjacent to the bearing surfaces soon after birth.

Exceptions: Every long bone does not conform to all the foregoing specifications. For example, the *clavicle*, has no marrow cavity; it is largely preformed in membrane; and only one end is enlarged. Again, the *terminal phalanges* of the hand and foot, are non-articular at their distal ends, are tapering, and have no medullary cavity.

The *ribs*, though usually classified as flat bones, are certainly not lacking in length. Except that they are somewhat flattened and have no medullary cavity, they fulfil the specifications of a long

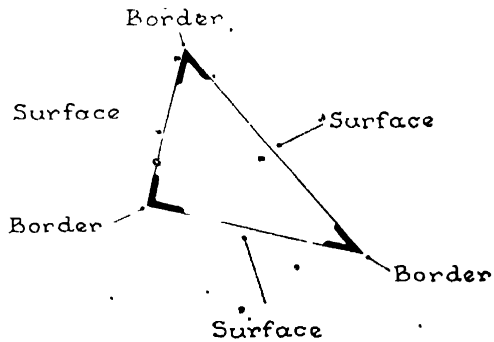

FIG. 12. The 3 borders are unbendable, like angle-iron.

bone. The *vertebrae* are classified as irregular bones, but their bodies possess most of the features of a long bone.

SHORT BONES are cubical. They are confined to the carpus and tarsus. In structure they are almost identical with the epiphyseal ends of long bones. They have six surfaces of which four (or less) are articular, leaving two (or more) free for the attachment of ligaments and for the entry of blood vessels. They develop in cartilage, and they begin to ossify soon after birth.

Of the short bones, 3 (calcaneum, talus, and cuboid) start ossifying before birth; so do the epiphyses of 3 long bones

(knee end of femur and tibia and commonly the shoulder end of humerus).

FLAT BONES resemble sandwiches. They consist of two layers or plates of compact bone with spongy bone and marrow spread between them. Many of the skull bones (e.g., parietal, vomer), the sternum, ribs, scapulae and parts of other bones are of the flat type. Most flat bones help to form the walls of rounded cavities and therefore are curved. At birth a flat bone consists of a single plate. The spongy bone and marrow, called *diploe* in the cranial bones, appears some years later and splits the plate into two. The marrow may, however, be spread unevenly leaving the plate single and translucent in parts. To verify this, hold the occipital, squamous temporal, scapula or ilium to the light.

IRREGULAR BONES have any irregular or mixed shape. All skull bones, not of the flat type, are irregular (e.g., sphenoid, maxilla), so are the vertebrae and the hip bones. They are composed of spongy bone and marrow within a compact covering.

Pneumatic Bones. Evaginations of the mucous lining of the nasal cavities and of the middle ear and tympanic antrum invade the diploe of certain flat and irregular bones of the skull thereby producing *air cells* or *air sinuses*. This pneumatic method of construction may be economical in bone material, but it invites "colds in the head" and other infections of the nose and throat to extend to these sinuses.

SESAMOID BONES are nodules of bone that develop in certain tendons where they rub on convex bony surfaces. ("Sesamoid" of Arabic origin = like a seed; cf. "open sesame" of Ali Baba and the Forty Thieves.) The free surface of the nodule is covered with articular cartilage; the rest is buried in the tendon; it possesses no periosteum. (See p. 17.) The most important occur in: Quadriceps Femoris (patella), Flexor Hallucis Brevis (2 at ball of big toe), Flexor Pollicis Brevis (2 at ball of thumb), Flexor Carpi Ulnaris (? pisiform), lateral head of Gastrocnemius (fabella), Peroneus Longus (at side of cuboid), Tibialis Posterior (behind scaphoid), palmar plates at the heads of metacarpals 2 and 5.

Supernumerary or Accessory Bones. Certain bones normally ossify from several centres, and it sometimes happens that one or more of these centres fails to unite with the main mass of the bone; again, an abnormal or extra centre of ossification may make its appearance and the resulting bone may remain discrete. In either case, the result is an accessory bone. These are commonest in the skull, and at the wrist and ankle. In X-ray photographs accessory bones simulate fractures. They are, however, usually bilateral; so, X-raying both sides of the body may aid in making a correct diagnosis; also, their edges have a covering of compact bone, which fractured bones have not.

Examples: The right and left halves of the frontal commonly fail to unite; ununited upper parts of the occipital (interparietal and preinterparietal) and sutural or Wormian bones (i.e., bones in the sutures of the vault of the skull, about the size of a finger nail) are not uncommon; bipartite parietal and zygomatic bones are rare; the distal epiphysis of the acromion commonly remains discrete (*fig. 78*); the 5th lumbar vertebra is commonly in two pieces (*fig. 298*); the patella may be bipartite (*fig. 489*). Supernumerary carpals and tarsals occur (p. 489).

Markings on a Dried Bone. The surface of a dried bone is smooth, in fact almost polished, over areas covered with

cartilage and where tendons play in grooves (cf., head of the humerus and the bicipital groove; upper and under surfaces of the sustentaculum tali). It is also smooth where the fleshy fibres of muscles are attached. Near the ends of a long bone there are large vascular foramina for veins and arteries; and piercing the shaft obliquely is the nutrient canal, for the medullary artery, which may be two inches long. Markings occur wherever fibrous tissue is attached—no matter whether it be a ligament, tendon, aponeurosis, fascia, intermuscular septum or fold of dura mater (falx and tentorium). Fibrous-tissue markings are, however, not present at birth nor in the young (e.g., they are not seen on a soup bone). They appear about puberty and they become progressively better marked with advancing age.

Markings take the form of (a) elevations, (b) facets, and (c) depressions. Elevations, in order of prominence:—a linear elevation is a *line*, *ridge*, or *crest*; a rounded elevation is a *tubercle*, *tuberosity*, *malleolus*, or *trochanter*; a sharp elevation is a *spine* or *styloid process*. Small, smooth, flat areas are called *facets* (cf., the facet of a diamond). A depression is a *pit* or *fovea*, if small; a *fossa*, if large; a *groove* or *sulcus*, if it has length. A *notch* or *incisura*, when bridged by a ligament or by bone is a *foramen* (i.e., a perforation or hole), and a foramen that has length is a *canal* or *meatus*. A canal has an orifice at each end; (the external auditory meatus, however, is an exception). The portion of a notch, foramen, or orifice of a canal over which an emerging vessel or nerve rolls is rounded, but elsewhere it is sharp. Therefore, even on a dried bone the direction taken by the emerging occupant is evident (cf., lesser sciatic notch, anterior sacral foramina, infra-orbital canal).

Areas covered with articular cartilage are called *articular facets*, if approximately flat. Certain rounded articular areas are called *heads*, others *condyles* (= knuckles). A *trochlea* or pulley is usually a concavo-convex (saddle-shaped) articular area.

Note, then, on the dried bone (1) that the area of attachment of the fleshy fibres of a muscle cannot be determined by inspection, but (2) that tendons, ligaments, and other fibrous structures make their mark, and (3) that the mark indicates precisely the limits of their attachments.

A Living Bone or a Dissecting Room Specimen Before Maceration. The articular parts are covered with *hyaline* (articular) *cartilage*. This is not equally thick at all points; so, its contour is not identical with that of the underlying bone. Hence, macerated bones do not articulate perfectly. *Periosteum* envelops all parts not covered with cartilage and not giving attachment to ligaments and tendons. It consists of two layers (1) an outer, fibrous membrane and (2) an inner, vascular one lined with bone-forming cells, the *osteoblasts*. The periosteum is easily scraped off with the handle of the scalpel, leaving, however, many osteoblasts adhering to the bone. *Fibrocartilage* lines grooves where tendons exert pressure. Some elevations seen in the macerated bone are but shadows of what they were before maceration, because in life they had fibrocartilaginous extensions now shed. (e.g., the dorsal radial tubercle of Lister before maceration was continued up the radius as a fibrocartilaginous ridge that gave attachment to the extensor retinaculum).

The Parts of a Young Bone (*fig. 13*). At birth both ends of a long bone are cartilaginous masses, *cartilaginous epiphyses*, (Gk. epi = upon: phusis =

growth). The part of the bone between the cartilaginous ends is the *diaphysis* (Gk. dia = in between, across). It comprises a casing of compact bone which encloses a medullary cavity at its middle and spongy bone at each end, and all is filled with red marrow. The diaphysis is clothed in *periosteum*; this is structurally continuous with the *perichondrium* which clothes and adheres to the cartilaginous ends, except, of course, on articular surfaces.

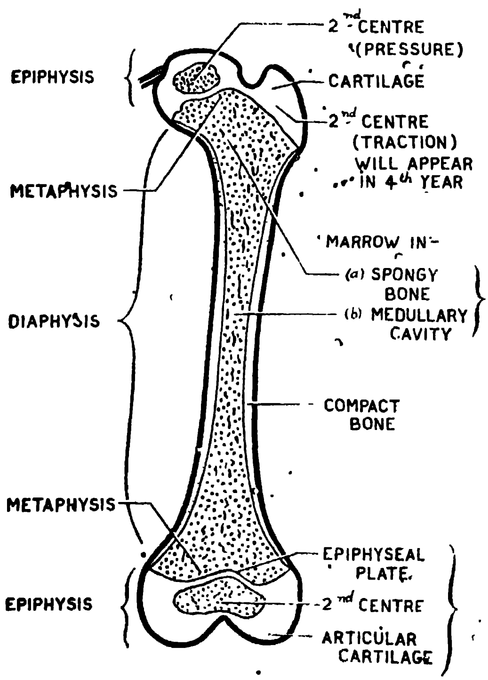

FIG. 13. The parts of a young bone as shown by a longitudinal section of a femur.

Epiphyses. (1) During the first and second years one (or both) of the cartilaginous epiphyseal ends begins to ossify subjacent to the site of articulation, constituting a *pressure epiphysis* (e.g., head of humerus, condyles of femur). (2) Later, generally about puberty, independent ossific centres appear in the cartilage at the sites of attachment of certain tendons, constituting *traction epiphyses* (e.g., tuberosities of humerus, trochanters of femur). (3) A third type of epiphysis is the *atavistic epiphysis*. Atavistic epiphyses phylogenetically were independent bones now grafted on to other bones (e.g., coracoid processes of scapula, posterior tubercle (os trigonum) of talus).

The layer of cartilage between an ossifying epiphysis and a diaphysis is an *epiphyseal plate*. The region of the diaphysis adjacent to the plate, the *metaphysis* (Gk. meta = beyond), is the site where growth in length takes place.

All long bones—including the metacarpals, metatarsals, and phalanges—have a pressure epiphysis at one end or the other; 5 paired bones always have pressure epiphyses at both ends (viz., humerus, radius, femur, tibia and fibula) and a few bones occasionally have them at both ends (viz., clavicle, 1st and 2nd metacarpals and 1st metatarsal). The ulna also has an epiphysis at each end, but the proximal one is a traction epiphysis due to the pull of the Triceps tendon.

A pressure epiphysis has been regarded as a protective cap to the metaphysis or actively growing portion of a bone.

Increasing deposits of periosteal bone cause the nutrient canal (which early ran transversely) to occupy an oblique position directed away from the epiphyseal end—or, in cases where there is an epiphysis at each end, from the more actively growing end. Accordingly, growth being more active at the shoulder and wrist than at the elbow, and at the knee than at the hip and ankle, the canals are directed towards the elbow and away from the knee. Further, where there are two epiphyseal ends, the one that has most work to do (i.e., that makes the greater contribution to growth in length) is the first to start ossifying and the last

to fuse with the diaphysis. When fusion (synostosis) takes place, growth in length practically ceases. Ossification starts earlier in females than in males and is completed earlier, even by as much as two or three years.

Ossification. There are two types of ossification (a) intracartilaginous or enchondral and (b) periosteal or intramembranous. In a long bone both types take place concurrently. Quite arbitrarily the process of ossification may be divided into seven stages: (1) The diffuse mesoderm, *mesenchyme*, in the central axis of the limb of the embryo condenses to form a long rod of denser mesenchyme. This is divided by less dense areas (which mark the sites of the future joints) into segments corresponding to the future bones. (2) Each condensed segment turns into hyaline cartilage and assumes the shape of the future adult bone; it is a cartilaginous model. (3) In the centre of the model the cells enlarge and form longitudinal rows, and calcium salts are deposited around them, forming calcified cartilage. This process advances towards both ends of the bone. (4) The osteoblasts in the perichondrium enveloping the cartilage lay down bone, layer upon layer—so, the perichondrium must now be called periosteum. This process, which is independent of the cartilage, is an example of periosteal or intramembranous ossification. (5) Vessels and accompanying cells from the periosteum burst through, as an expanding bud, into the calcified cartilage, which breaks down before them, lay down temporary spongy bone and give rise to bone marrow. This process now advances towards both ends of the bone, and ultimately the calcified cartilage is completely replaced by spongy bone. This process, replacing cartilage, is the enchondral type of ossification. About the 6th month, resorption of the central part of the spongy bone leads to the formation of a medullary cavity. (6) After birth, at the centre of one or both cartilaginous ends, the process of enchondral ossification is repeated—in short an epiphysis takes form. Ossification progresses in the epiphysis until only two sheets of cartilage remain (a) the *articular cartilage* that covers the end of the bone and persists throughout life, and (b) a residual plate, the ***epiphyseal plate***, placed between the diaphysis and the bony epiphysis forming a synchondrosis. (7) Ultimately, when the bone has attained its adult length, the plate also ossifies, that is, synostosis results—the site commonly being marked by an *epiphyseal line* (*fig. 11*).

Short bones ossify enchondrally like epiphyses. The clavicle and all the bones of the skull, except those of the base, are not preformed in cartilage but ossify directly from membrane, as in item (4) of the preceding paragraph. The bones of the base preformed in cartilage are (a) occipital, save the interparietal part; (b) sphenoid, save the greater wings and the medial pterygoid laminae; (c) ethmoid; (d) inferior conchae; and (e) temporals, save the squamous and tympanic parts.

Bone Marrow makes blood cells. Blood cells have but a short life, the red cells living only about six weeks, and the birth rate necessarily keeps pace with the death rate.

At birth spongy bone, which at this age is limited in quantity, and the medullary cavities of the long bones are filled with red (blood forming) marrow. By the 7th year, the amount of spongy bone has increased and the red marrow has extended into it, but at the same time has receded from the medullary cavities only to be replaced there by yellow (fatty) marrow. By the 14th year (puberty)

red marrow is almost entirely replaced by yellow in the limb bones; thereafter, it is confined to the axial skeleton—skull, vertebrae, ribs, and sternum. In certain conditions (e.g., pernicious anaemia) where the death rate of the red cells is high, the yellow marrow reverts to red in an endeavour to support the birth rate.

Vessels and Nerves. ARTERIES supply long bones thus: (a) *periosteal twigs* enter the shaft at innumerable points, run in the Haversian canals and supply the outer part of the compact bone of the shaft; (b) twigs from arteries which anastomose *around the joint* (usually between the bone and the reflexion of the synovial membrane) supply the ends of the bone; (c) the *nutrient (medullary) artery* divides into a proximal and a distal branch; these supply the marrow, the metaphyses and the inner part of the compact bone, and they anastomose with the periosteal twigs in the Haversian canals and with the arteries around the joint; (H. A. Harris regards the branches of the nutrient artery virtually as end arteries to the metaphyses.)

VEINS. There are periosteal veins and medullary or nutrient veins, but the chief veins, enriched with young blood cells, escape by the large foramina near the ends of the bone.

LYMPH VESSELS exist in the periosteum and in the perivascular lymph spaces in Haversian canals.

NERVES. Sensory nerves are plentiful in the periosteum, and nerves ((?) vasomotor) accompany the nutrient artery.

The vessels in the bony canals can neither contract appreciably nor dilate. In fractures, therefore, blood continues to ooze from the broken ends of the bone; in acute inflammation, the vascular reaction being ineffective, local death results.

Historical. One day in 1736, John Belchier, surgeon on the staff of Guy's Hospital, London, was dining with a friend. A joint of pork was served, and it was commented that the bones were red. The host, who was a calico-printer, explained that he utilised bran soaked in madder from his dye vats to feed his pigs, and to this he attributed the colour. Belchier communicated this fact to the Royal Society, and it was printed in its transactions.

Duhamel, a French squire, read Belchier's paper and, being curious, fed madder to some of his fowls and pigs; and with the same red result. He then conducted a number of experiments on pigs and found that if the animals were killed while the feeding of madder was in progress, the bones appeared red, and that if the feeding of madder had ceased for a period the bones appeared white. On laying open the bones, he found that though they were white outside they were red inside. By alternately feeding food with madder and without, he produced bones with alternating red and white rings or layers, so he concluded that bones increase in girth like trees and that the periosteum is responsible for laying down the rings. He encircled growing bones with rings of silver wire and in time he found the wire inside the medullary cavity, because the cavity too had enlarged —but he did not understand how.

In the shaft of a growing bone Duhamel bored holes at measured distances apart, and in them inserted silver stylets to keep them open. After a period he killed the animal and found that, though the length of the bone had increased, the holes remained the same distance apart, so he concluded that growth in length takes place at the ends of the long bones.

John Hunter sought further explanation. Knowing that the lower jaw has no epiphyses and that the milk teeth of a child fill the body of the jaw right back

to the ramus, he wondered how space was found for the three additional teeth, the three permanent molars. He surmised that the growth of bone entails two processes—one of deposition (addition), the other of absorption (subtraction). Only thus could he account for the growth of the jaw, the formation and progressive enlargement of medullary cavities, and for changes in the neck of the femur (*fig. 14*). About 1764, John Hunter—employing on pigs madder feeding experiments and using controls—put his theory to the test and proved it to be correct. (Consult "Menders of the Maimed" by Sir Arthur Keith.)

Recently, Brash's extensively planned madder experiments have shown that the skull bones grow not at the suture lines but through additions to their outer surfaces while subtraction takes place pari passu on their inner surfaces, (i.e., the pericranium deposits, the endocranium removes). And by a similar process the tooth sockets move forward as the jaws enlarge.

H. A. Harris has shown that the growt of the skeleton is sensitive to relativel slight and transient illnesses and t periods of malnutrition; that when child is ill or starved, its epiphyse plates, ceasing to proliferate, becom heavily calcified; and that when growth resumed, this line of arrested growt appears as a veritable scar. The sea sonal rings in deciduous trees and the annual rings on the scales of fish likewise bear evidence of growth retarded or arrested and its resumption. Figure *15* makes clear his statement that "since the transverse striations remain steadfastly parallel and equidistant, we now have convincing proof that there is no interstitial growth in length in the shaft of the tibia, and all growth in length takes place by the apposition of new bone to the ends of the diaphysis at the growth cartilages".

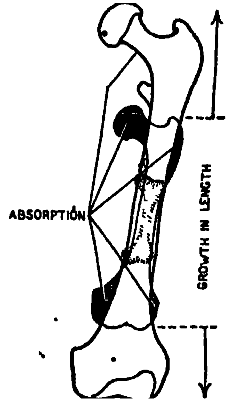

FIG. 14. Remodelling of bone. As a long bone grows, sites once occupied by the expanded ends become parts of the more slender shaft; hence remodelling occurs. Further, bone is deposited on the upper aspect of the neck of the femur and absorbed on the lower. It is obvious that growth at the upper metaphysis of the femur will lengthen the neck only.

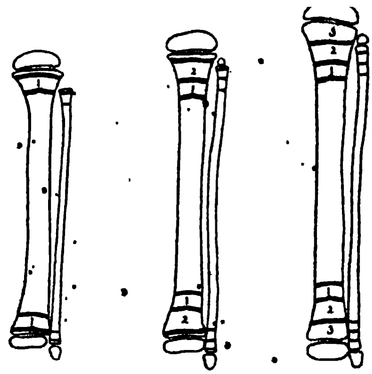

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FIG. 15. Outlines of 3 radiograms of the leg bones of a young girl taken over a period of two years. Observe that the 3 lines of arrested growth, denoting 3 successive illnesses, remain equidistant. (After H. A. Harris.)

When a particulate radio-opaque substance, such as thorotrast, is injected into the bloodstream, it is taken up by the reticulo-endothelial cells and apparently it is retained by them indefi-

nitely. Hence, the spleen and liver cast a positive shadow on an X-ray plate, and so does the bone marrow. Employing this technique experimentally in young animals, Mortensen and Guest have shown that, while the expanded ends of a long bone grow farther apart and the medullary cavity enlarges correspondingly, the shadow cast by the part of the marrow infiltrated remains constant in length and the actively growing ends gradually recede from it. This substantiates the work referred to above.

Cartilage

Cartilage or gristle is a connective tissue in which a solid ground substance replaces tissue fluids. It has no blood vessels, lymph vessels, or nerves; so, it is insensitive. There are three types of cartilage: (1) hyaline, (2) fibro- and (3) elastic.

Hyaline Cartilage (Gk. (h)ualos = a transparent stone) is white and resilient. It is potentially bone; in fact, all the bones, except certain skull bones and the clavicle, were preformed in hyaline cartilage. In the adult, hyaline cartilage persists at the articular ends of bones as articular cartilage, at the sternal ends of the ribs as costal cartilage, and as the cartilages of the nose, larynx, trachea, and bronchi. The thyroid, cricoid, and 1st costal cartilages commonly begin to calcify about the 40th year. Perichondrium (equivalent to periosteum) which envelops hyaline cartilage is not present over articular cartilage.

Microscopically, it appears as cells singly, in pairs, or in fours (like a hot cross bun) enclosed in capsules and lying in a clear matrix. The cells may form rows.

Fibrocartilage has the same structure as fibrous tissue (aponeurosis, ligament, *fig. 52*) save that, the ground substance being solid, the cells are not squeezed into stellate form by the bundles of fibrous tissue, but are round. Fibrocartilage bears the same resemblance to fibrous tissue that a starched collar bears to a soft collar. Wherever fibrous tissue is subjected to great pressure, it is replaced by fibrocartilage. It occurs in intervertebral discs, articular discs (e.g., semilunar cartilages of the knee), glenoid and acetabular labra, and the surface layers of tendons and ligaments that are pressed on by bone. It lines certain bony grooves in which tendons play and it caps certain bony prominences. It is tough, strong, and resilient.

Elastic Cartilage. Here cartilage cells are numerous and the solid ground work is pervaded by elastic fibres; so, it looks yellow. It is found only in the external ear, external auditory canal, pharyngo-tympanic tube, and the cartilages guarding the upper aperture of the larynx (epiglottic, cuneiform, corniculate, and part of the arytenoid). Being elastic, when bent it springs back into shape (e.g., the auricle). It is, however, not tough.

THE PARTS OF A TYPICAL VERTEBRA AND THEIR FUNCTIONS

The vertebral column is made up of 33 vertebrae, arranged as follows: 7 cervical 12 thoracic, 5 lumbar, 5 sacral, and 4 coccygeal. The sacral and coccygeal vertebrae form composite bones, namely, the os sacrum and os coccygis. The 5 sacral vertebrae have fused to form a single mass by the 25th year; the last three pieces of the coccyx fuse together in middle life and these in turn fuse with the first piece still later. There are, therefore; 24 presacral or true vertebrae, of which 12 bear ribs and 12 do not.

Not only have the bones of each region features characteristic of their particular region but every bone in each region has

one or more distinguishing features of its own.

A vertebra is composed of the following parts (*fig. 16*):

a. A weight-bearing portion—the *body*.

b. A part that protects the spinal cord—the *vertebral arch*.

c. Three levers on which muscles pull—the *spinous process;* the right and the left *transverse process*.

d. Four projections which restrict movements—two superior and two inferior *articular processes*.

The Body is for functional and structural reasons to be classified as a long bone (*fig. 17*) Thus, it resembles the long bones of the limbs in that it is weight-supporting, constricted about its middle, enlarged at its two ends, and in that its two ends are articular; also in having a primary center of ossification for the "diaphysis" which appears early, and secondary centers for the upper and lower epiphyses, which however appear unduly late for pressure epiphyses. It is, indeed, a long bone in miniature.

Its early development is peculiar: during the precartilaginous state each of a series of protovertebral somites, that develop around the notochord, splits into a cranial and a caudal half; thereupon the adjacent halves of two somites unite to form a body. Large vascular foramina persist behind and at the sides of adult vertebral bodies and indicate the site of union of two half segments. The body of a vertebra is, therefore, not a segmental structure, but a composite of two half segments.

The Vertebral Arch protects the spinal cord from injury, as the roof of the cranium protects the brain. On each side a spinal nerve crosses the arch immediately behind its attachments to the body; accordingly, the anterior part of each arch, called the *root* or *pedicle*, is grooved, especially on its lower border, so as to allow ample space for the passage of a nerve. These are the *superior* and *inferior vertebral notches*. The posterior band-like portions of each arch, the *right* and *left laminae*, meet behind in the middle line. A vertebral arch and the posterior aspect of a body enclose a

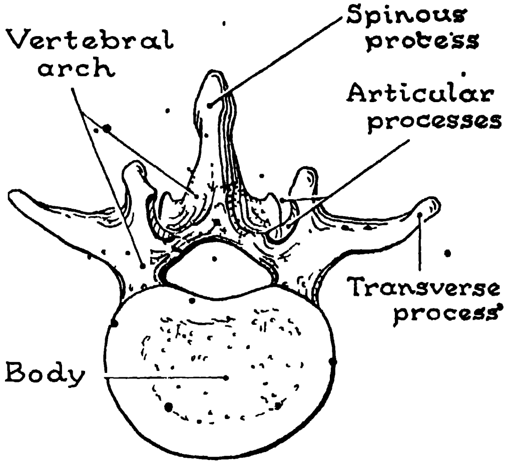


FIG 16. The parts of a vertebra, from above

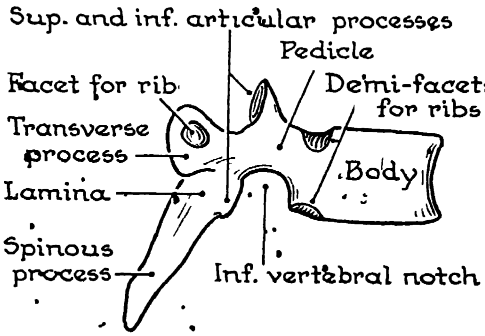


FIG. 17. A typical vertebra (side view).

space, the *vertebral foramen*, in which the spinal cord and its membranes are lodged.

The movement of one body on another is effected in part through the actions of muscles on the lever-like **Transverse and Spinous Processes**, which project like the spokes of a capstan. The transverse processes project laterally on each side

from the junction of a pedicle and a lamina; the spinous process or spine projects backwards in the median plane from the site of union of a right and a left lamina.

The so-called Articular Processes arise near the junction of pedicle and lamina. The superior processes spring rather from the pedicles and face in a backward direction (backwards and upwards in the cervical region; backwards and laterally in the thoracic region; backwards and medially in the lumbar region) whereas the inferior articular processes spring from the laminae and face in the contrary direction. It is evident that in all regions the contact established between upper and lower articular processes prevents forward displacement of an upper vertebra on a lower.

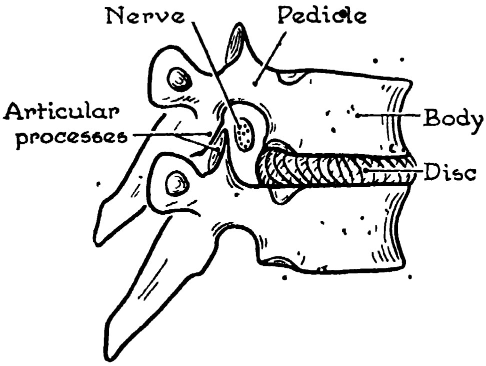


FIG. 18. Composition of an intervertebral foramen.

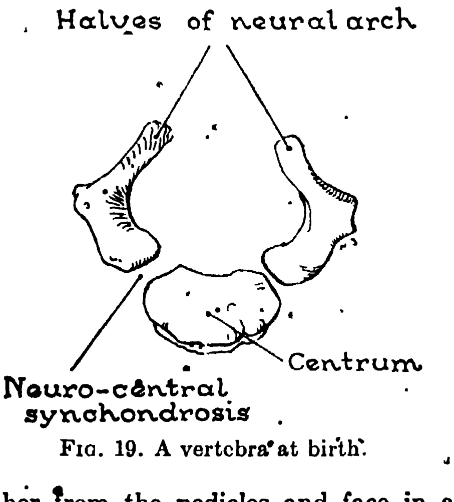


FIG. 19. A vertebra at birth.

The upper and lower surfaces of the bodies are the real articular surfaces of the vertebrae. The so-called articular processes (except in the case of the atlas and axis) do not transmit weight. Their presence interferes with the unrestricted mobility the bodies might otherwise enjoy and decrees in what direction movements between two adjacent vertebrae shall be allowed. They play the part which in the joints of the limbs is assigned to ligaments, namely that of restricting movement. There are, however, circumstances in which they bear weight, e.g., on rising from the stooping position. L. 5 is "normally" in a stooping position.

Collectively the vertebral foramina constitute the *vertebral canal.* Collectively two adjacent vertebral notches constitute an *intervertebral foramen.* Entering into the composition of an intervertebral foramen of an articulated column are: above and below, pedicles; in front, an intervertebral disc and parts of the bodies it unites; and behind, the capsule enveloping an upper and a lower articular process (*fig. 18*).

Ossification. At birth a vertebra is in three parts—a *centrum* and the right and left sides of a *neural arch*, united to each other by hyaline cartilage (*fig. 19*). The site of union of a centrum and a neural arch is a *neuro-central synchondrosis.*

The facets for the heads of the ribs are situated on the neural arches just behind the neuro - central synchondroses;—— they are not on the sides of the centra.

Synostosis of the two sides of the arch takes place posteriorly during the 1st year; synostosis of the neuro-central synchondrosis takes place between the 3rd and 6th years.

Epiphyses. Pressure and traction epiphyses appear about puberty and fuse about the 25th year. In most mammals the pressure epiphyses take the form of plates, but in man they are rings, that overlie the upper and lower surfaces of the centrum and extend on to the neural arch. The body of a vertebra comprises the upper and lower epiphyses and the mass of bone between them. It includes therefore the centrum, part of the neural arch, and the facets for the heads of the ribs. The terms "body" and "centrum" are not, therefore, strictly speaking interchangeable; neither are the terms "vertebral arch" and "neural arch". Scale-like traction epiphyses appear on the tips of the spinous, transverse, and (in the lumbar region) mamillary processes.

Cervical vertebrae (p. 695); thoracic vertebrae (p. 491); lumbar vertebrae (p. 295); sacrum and coccyx (p. 326).

ARTICULATIONS OR JOINTS

A joint is a junction between two or more bones Joints may be classified as—immovable, slightly movable, and freely movable; but perhaps it is more helpful to consider them as:

1. The *skull type:* Immovable; or temporary joint.
2. The *vertebral type:* Slightly movable; or secure joint.
3. The *limb type:* Freely movable; insecure; or synovial joint.

The Skull Type

The skull type is either a suture or a synchondrosis depending on whether the bones concerned ossify in membrane or in cartilage; it is immovable (*fig. 23*).

Suture. When the growing edges of two bones (or ossific centers) developing in membrane come together, a residual film of membrane may persist unossified between them for some years, till middle age, or indefinitely. Such a union is called a suture; and sutures are confined to the skull (*fig. 20*). The edges may interlock in jig-saw fashion (denticulate s.) or like the teeth of a saw (serrate s.). They may be bevelled and overlapping (squamous s.), or relatively flat and abutting (plane or harmonious s.). A ridge may fit into a groove as between sphenoid and vomer, or a tooth may fit into a socket.

Synchondrosis. Similarly when the growing edges of two bones (or ossific centers) developing in a single mass of cartilage come together, a residual plate of cartilage may persist unossified between them for a number of years. Such a union is a synchondrosis.

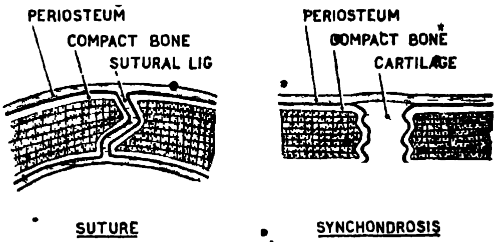


FIG. 20. A suture and a synchondrosis.

Sites. Synchondroses occur at the base of the skull between the basi-occipital and basi-sphenoid, sphenoid and ethmoid, petrous-temporal and basi-occipital, and petrous-temporal and jugular process. Their distribution however is widespread, for is it not by synchondroses (epiphyseal plates) that epiphyses are united to bones (*fig. 13*)?

Synostosis is the obliteration of a suture or a synchondrosis by bone. It is associated with cessation of growth locally.

The Vertebral Type

The vertebral type is either a symphysis or a syndesmosis. Intervertebral joints are built for safety and security; so, their opposed bony surfaces are firmly

bound together. This minimizes the risk of dislocation, which here would be disastrous; it also greatly restricts mobility.

A Symphysis is a joint where two opposed bony surfaces are coated with hyaline cartilage, are united by fibro-cartilage, and are further united in front and behind by ligamentous bands. There is no joint cavity, but a small cleft may be present. Symphyses are not directly controlled by muscles.

Sites. Symphyses occur between (a) the bodies of vertebrae, (b) between the pubic bones, and (c) between the manubrium and body of the sternum.

THE SYMPHYSIS BETWEEN TWO VERTEBRAL BODIES (*figs. 21, 22*). The body of a vertebra is a miniature long bone. It is constricted at its middle and enlarged at its ends, both of which carry epiphyses. In mammals generally these epiphyses are bony plates, but in man they are bony rings resembling tambourines, because only the periphery of each epiphysis ossifies and the center remains hyaline. The epiphyses fuse with the body before the 25th year.

Intervertebral Discs. Adjacent bodies are united by a fibro-cartilaginous disc whose peripheral part is composed of about a dozen concentric layers of fibers, the *annulus fibrosus*. The fibers in alternate layers cross like the fibers of the External and Internal Intercostal muscles. The center of the disc is filled with a fibro-gelatinous pulp, the *nucleus pulposus*, which acts as a cushion or shock absorber and, being under pressure, bulges when the disc is cut across.

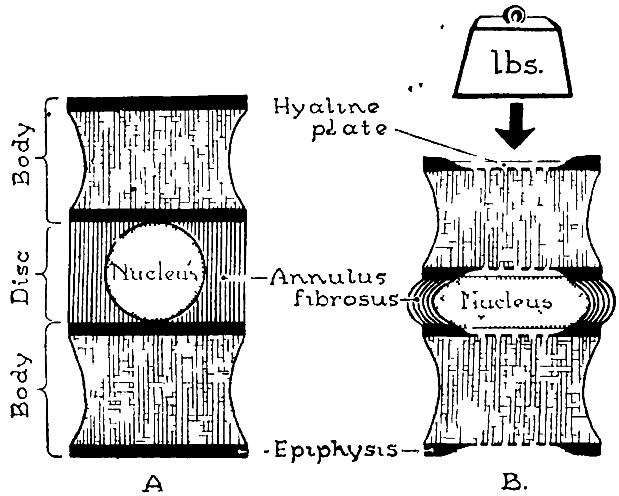


FIG. 21 Scheme of an intervertebral disc.

It has been shown by experiment on the fresh cadaver that the turgor of the 4th lumbar disc exerts an expansile pressure of 32 lbs.; it has also been shown that, when the pedicles of the lumbar and lower thoracic vertebrae are sawn through and the longitudinal ligaments and the annuli fibrosi divided, the average expansion of the discs is 1.08 mm. (Petter).

Longitudinal Ligaments, an anterior and a posterior, extend from the sacrum to the basi-occiput: the one is attached to the intervertebral discs and adjacent margins of the vertebral bodies anteriorly; the other is attached to them pos-

teriorly, i.e., within the vertebral canal. The anterior ligament is a broad, strong band, except above, where it becomes a cord that gains attachment to the anterior tubercle of the atlas and extends above it to the basi-occiput. The posterior ligament is weak and narrow, but it widens in a denticulate manner at its attachments to the discs. Its upper end is the membrana tectoria (p. 702).

Vessels and Nerves. The disc is nonvascular. Branches of the spinal nerves have been traced to the longitudinal ligaments and to the annulus (Roofe; and others).

Note. (a) the hyaline plate is apt to crack and the nucleus pulposus to herniate through it into the cancellous body of the vertebra; and (b) the pulp may burst through the annulus fibrosus posteriorly, where it is thinnest, and protrude under cover of the posterior longitudinal ligament. These accidents happen commonly.

A SYNDESMOSIS is a union by ligamentous fibers, the bony points united being some distance apart.

Sites. Syndesmoses occur between the vertebral arches and between the leverlike processes of the vertebrae, also between coracoid and acromion (coracoacromial lig.), between coracoid and clavicle (coraco-clavicular lig.), and between the bones of the forearm and of the leg (interosseous membranes) including the inferior tibio-fibular joint.

THE VERTEBRAL SYNDESMOSES. The laminae of adjacent vertebrae are united by yellow elastic bands, called the *ligamenta flava.* These broad bands unite the upper border and posterior surface of one lamina to the lower border and anterior surface of the lamina above. In virtue of their elasticity, the ligamenta flava serve as "muscle sparers", i.e., they assist in the recovery to the erect posture after bending forwards and they are particularly strong in the lumbar region.

The adjacent borders of the spinous processes are united by weak *interspinous ligaments* and their tips are united by stronger *supraspinous ligaments,* which in the neck become the *ligamentum nuchae* (p. 702). The transverse processes may be connected by weak *intertransverse ligaments.*

The articular processes of vertebrae are united by joints of the limb type. They have synovial cavities closed by

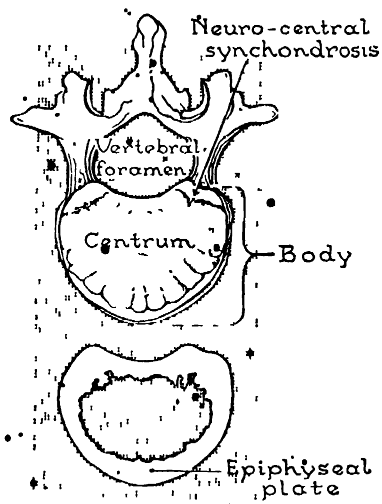


FIG. 22. A vertebra in childhood.

fibrous capsules. In the lumbar region lateral extensions of the plate-like lig. flava close the joint cavities anteriorly.

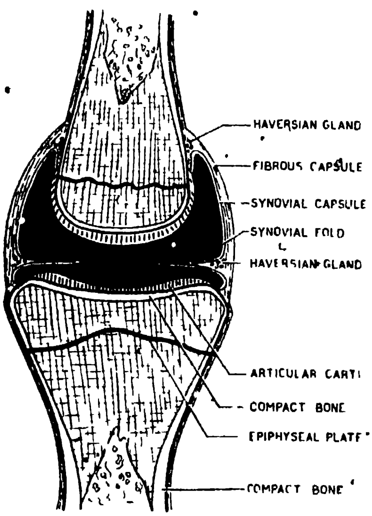
The Limb Type

The limb type is commonly called a *synovial joint.* The limbs being primarily organs of locomotion have joints which permit free movement; so, the site which in a symphysis is occupied by fibro-cartilage becomes a joint cavity. This makes for insecurity.

At the limb type of joint two or more bones are united by a sleeve of fibrous

tissue, called the *fibrous capsule,* within which there is an inner tube of synovial membrane, the *synovial capsule,* and the opposed ends of the bones are covered with hyaline cartilage.

It is helpful to think of a joint cavity as a bursa originally lined throughout with synovial membrane, and to think of this synovial membrane as persisting except where it is worn away at areas of pressure and of friction. At these sites there is either hyaline cartilage or fibro-cartilage. Joint cavities, then, are lined either with



SYNOVIAL OR LIMB TYPE OF JOINT

FIG. 23. A synovial or limb joint.

synovial membrane, hyaline cartilage, or fibro-cartilage, and are usually called *synovial cavities.*

A synovial membrane is an areolar sheet developed from mesenchyme and lined irregularly with cells that vary in shape: in places the cells are absent; in other places they are two deep. The membrane can be dissected from the fibrous capsule and from the bone, but it is intimately adherent to the pressure surfaces of such fibro-cartilages and tendons as enter into joints. The film of lubricating, and perhaps nourishing, fluid within the synovial cavity resembles white of egg and is called the *synovial fluid.* The articular cartilage is constantly being worn away and incorporated with the synovial fluid and it is constantly being replaced, but the source of its nourishment is debatable. In early life the cartilage appears to be replaced by mitosis, later by amitosis (H. C. Elliott).

As stated on page 10, articular cartilage has neither blood supply, lymph supply, nor nerve supply.

Transparent *folds of synovial membrane* containing fat at their attached ends project into all synovial joints, commonly for a centimeter or further. These folds are practically constant in position and form, and they are present at all ages (*fig. 190*).

Ligaments. The fibrous capsule is thickened in parts to form cords and bands, called *ligaments,* which withstand temporary strains. Other ligaments are to be regarded as the detached tendons of muscles.

Vessels and Nerves supply the fibrous and synovial capsules.

Articular Discs, which are pads of fibro-cartilage interposed between the articular surfaces of two bones, are found in certain joints where double movements take place. On the proximal surface of the disc one type of movement takes place (e.g., flexion and extension); on the distal surface another type of movement (e.g., rotation or gliding).

Bursae. (p. 25). Certain subtendinous bursae constantly communicate with synovial cavities, e.g., the Biceps and Subscapularis bursae at the shoulder, the Popliteus and Quadriceps bursae at the knee, the Tibialis Anterior bursa at the tarso-metatarsal joint; others do so inconstantly, e.g., the Psoas b. at the hip and the Gastrocnemius b. at the knee.

Labra: Fibrous tissue, subjected to great pressure and friction, gives place to fibro-cartilage, e.g., articular discs. Some joints, e.g., the shoulder and hip, have their sockets deepened by pliable rings of fibro-cartilage called labra.

Sesamoid bones are small bones found at the points of pressure of certain tendons that play across convexities. The most important are the patella, the two under the ball of the big toe, and the two at the ball of the thumb. They play on the distal ends of bones (e.g., femur, metatarsal, metacarpal) and never lie opposite the interval between two bones, where of course they could serve no purpose.

Haversian "glands" are pads of fat placed between a synovial and a fibrous capsule. Fat being fluid at body temperature, the pads can be sucked into the joints during certain movements, the formation of a vacuum being avoided thereby.

Epiphyseal plates: Before ossification is complete some part of the circumference of one or more adjacent epiphyseal plates commonly enters into the joint.

Ligaments and *tendons* may be situated between synovial and fibrous capsules, and they may project into the joint, but in all cases they are covered with synovial membrane. The Biceps at the shoulder and the ligament of the head of the femur are enveloped in synovial tubes.

The *relations* of joints obviously are of practical importance, and especially the relations of vessels and nerves. Main arteries keep to the flexor surfaces of joints. Here they are protected from injury, but, during flexion of the joint, they are bent and may thus be occluded; hence, a collateral circulation, such as is found at the elbow, wrist, knee, and ankle, serves as a useful by-pass.

Varieties of Synovial or Limb Joints. (1) *Plane*, arthrodial or gliding joint: The opposed bony surfaces are approximately flat, e.g., carpal joints and joints of the small tarsals.

(2) Uniaxial: (a) *Hinge* or ginglymus joint; one surface is concave, the other convex, and movement takes place on a horizontal axis, e.g., the elbow and ankle.

(b) *Pivot* or trochoid joint; a ring encircles a pivot set on a vertical axis, and rotation takes place as with a door on a hinge, e.g., atlanto-axial and radio-ulnar joints.

(3) Biaxial: Circumduction is permitted, i.e., on performing the movements of flexion, abduction, extension, and adduction in sequence a cone is described: (a) *Condyloïd* joint; one bony surface is a ball and the other a socket, e.g., the knuckles. (b) *Ellipsoidal* joint; one surface is an oval and the other a socket, e.g., the wrist.

(4) Multiaxial: The movements of circumduction and also of axial rotation are permitted, e.g., the shoulder and hip. (a) *Ball and socket* joint; a ball fits into a socket, the movements of circumduction and also of axial rotation are permitted. (b) *Saddle* joint; the surfaces are reciprocally saddle-shaped. Circumduction is allowed and during the movement some degree of axial rotation can take place, e.g., the carpo-metacarpal joint of the thumb.

THE ARTICULATED VERTEBRAL COLUMN

The bodies of the vertebrae contribute $\frac{3}{4}$ to the total length of the presacral portion of the articulated column; the intervertebral discs contribute $\frac{1}{4}$. (*Fig. 24.*)

The Intervertebral Discs. These fibro-cartilages are thickest (i.e., vertical height is greatest) where movement is most free; namely, in the cervical and lumbar regions, regions that are convex forwards; conversely they are thinnest where they

contribute to bony cavities; namely, in the thoracic and sacral regions. Indeed, in the adult they are ossified to form part of the composite sacral bone. Thus, they are thickest in the lower lumbar region and thinnest in the mid-thoracic region (T. 2-6). (*Fig. 25.*)

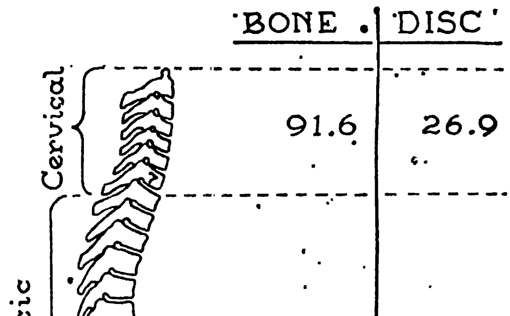


FIG. 24. Proportions of bone and disc in the presacral parts of the vertebral column. (Using Todd's data.)

Further, in the cervical and lumbar regions each disc is thicker ventrally than dorsally; whereas in the thoracic region the converse is the case; hence, in each region the disc contributes to the curvature of the column.

The Bodies of the Vertebrae. As might be expected, the size of a body depends upon the weight it supports The bodies accordingly increase in size progressively from the dens (which developmentally is the body of the atlas or 1st cervical vertebra united with the axis or 2nd cervical vertebra) to the first piece of the sacrum, and from there to the tip of the coccyx they diminish progressively. This is because the superimposed weight is transferred from the first three pieces of the sacrum to the ilium, thence to the femora when standing up and to the ischial tuberosities when sitting down. Stated otherwise: from the lumbo-sacral articulation the bodies taper gradually to the tip of the dens at one end of the column and to the tip of the coccyx at the other. To this the bodies of the first four thoracic vertebrae are an apparent exception because they diminish in width. The exception is, however, only apparent, because the upper and lower surfaces, which are the weight-bearing surfaces, do increase progressively from the 2nd cervical to the 5th lumbar as established by planimetry (George). The heights of the bodies (measured ventrally) also increase progressively from the lower cervical to the 5th lumbar.

The skull is not poised on the tip of the dens but on two facets, one on each lateral mass of the atlas; nor does one sit on the tip of ones coccyx but on the ischial tuberosities, the weight being transmitted to them by way of two facets, one on each lateral mass of the sacrum, which articulate with corresponding facets on the hip bones. Common sense suggests that the logical procedure to follow when called upon to reassemble the vertebrae of a disarticulated column is first to give consideration to the relative massiveness of the bodies and only later to regard such minor matters as the presence or absence of a facet, the shape

of a vertebral foramen, or the inclination of an articular process.

In lieu of a body, the *atlas* has an anterior arch which lies in front of the dens and of the plane of the bodies generally; it holds the lateral masses of the atlas together. The upper surface of the body of a *cervical* vertebra is oblong and, having upturned back and sides and rounded off front, it resembles a seat. The lower surface is the counterpart of this. The upper and lower surfaces of

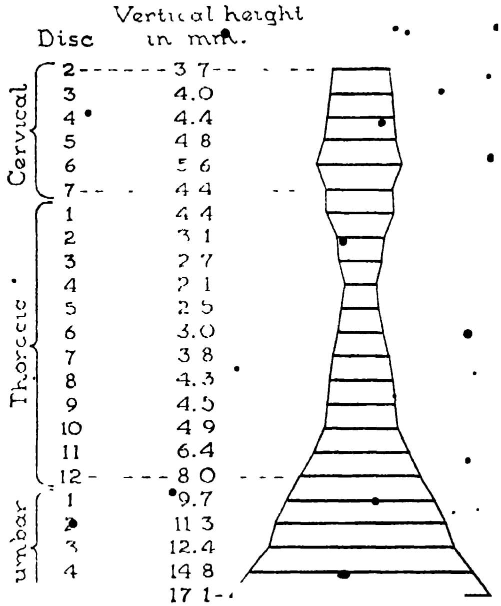


FIG. 25. Graph of the vertical heights of the intervertebral discs. (Using Todd's data.)

the thoracic and lumbar bodies are flat; the *thoracic* being heart-shaped with long diameter anteroposterior; the *lumbar* being kidney-shaped with long diameter transverse.

Curvatures: In embryonic life the vertebral column is uniformly curved so as to be concave ventrally (*fig. 26*). In the thoracic and sacro-coccygeal regions these concavities persist and thereby add to the capacity of the thoracic and pelvic cavities. The bodies of the thoracic and of most sacral vertebrae conform to the curvatures in being deeper behind than in front. The cervical and lumbar regions do not partake in cavities; so, by way of compensation they are convex ventrally. The cervical curvature (convexity) appears when the infant learns to hold its head erect and to direct its visual axes forwards, about the third month. The lumbar curvature (convexity) appears when the child acquires the art of walking erect, about the eighteenth month. The thoracic and sacral curvatures, therefore, are *primary curvatures*; the cervical and lumbar are *secondary or compensatory*.

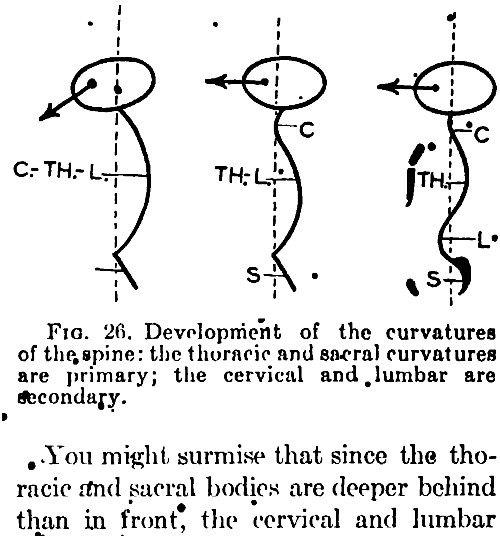


FIG. 26. Development of the curvatures of the spine: the thoracic and sacral curvatures are primary; the cervical and lumbar are secondary.

You might surmise that since the thoracic and sacral bodies are deeper behind than in front, the cervical and lumbar bodies would be deeper in front than behind. But, it is not so. These two unhampered regions are rich in intervertebral disc and therefore are supple. In the cervical region the bodies are of equal depth in front and behind; so, the cervical curvature is due solely to disc. In the lumbar region the 5th and 4th bodies are deeper in front, the 3rd and 2nd are variable, and the 1st is deeper behind.

Varying Stature. One may be shorter in the evening than in the morning be-

cause with fatigue (a) the curvatures of the spine may increase; (b) the turgor of the pulp of the intervertebral discs may be reduced; and (c) the height of the arches of the feet may be lessened. On the other hand, the stature may increase when one lies down.

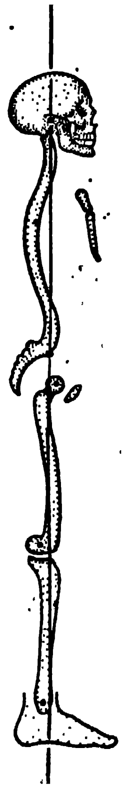


FIG. 27. The line of gravity.

The Line of Gravity passes through the dens of the axis, just in front of the sacral promontory, behind the centers of the hip joints, and in front of the knee and ankle joints (*fig. 27*).

Transverse Processes arise between upper and lower articular processes at the junctions of pedicles with laminae, and project laterally. In the *thoracic* region they act not only as levers for muscles but also as fulcra for the ribs; so, they are strong and stout and, in conformity with the backward curving of the ribs, they have a backward and upward inclination. Their tips bear articular facets, the shape and direction of which vary for reasons concerned with the mechanism of respiration (p. 501). The 11th and 12th ribs are floating; so, the transverse processes of the 11th and 12th vertebrae are reduced in size and carry no facets. The spread of the thoracic transverse processes diminishes from 1st to 12th.

Each *cervical* transverse process is perforated by a circular foramen, the *foramen transversarium.* The upper six foramina transmit the vertebral artery, a venous plexus, and sympathetic fibers; the 7th transmits small veins and is smaller than the others. Each, therefore, has two roots, a posterior and an anterior. All posterior roots end in tubercles for tendons; but of the anterior roots only the 3rd, 4th, 5th, and 6th have tubercles, the 6th being the largest. The processes and bodies collectively form an approximately flat anterior surface.

The *lumbar* transverse processes may be regarded as ossifications extending into the posterior aponeurosis of the Transversus Abdominis; so, they are thin and flat, except at their tips which take the pull of the muscle (*fig. 300*). From 1st to 5th their roots creep progressively further forwards towards the bodies, and they may be grooved in front by the nerves that cross them (*fig. 301*). Conforming to the shape of the rounded abdominal cavity they are directed but slightly backwards. They are not noted for their strength. Since the 4th lumbar vertebra lies at the level of the highest part of the iliac crest, it follows that the 5th lumbar vertebra must lie below the highest part of the crest; so, it is the only vertebra (except the

sacrum, capable of being suspended between the iliac crests, and on this depends the peculiar formation (*p. 332*) of its transverse processes.

A transverse process comprises two elements—a *costal* or rib element and a true or *morphological* transverse process. In all regions the transverse element arises between a superior and an inferior articular process; in all regions the costal element arises from the side of a body, except in the upper lumbar region, where

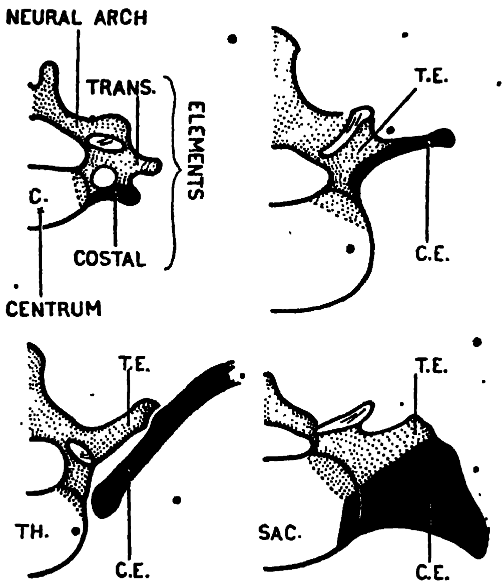


FIG. 28. Homologous parts of cervical, thoracic, lumbar, and sacral vertebrae. (clear = centrum; stippled = neural arch, transverse and spinous processes; black = costal element.)

fused elements arise between a pedicle and a lamina (*fig. 28*). In the *sacral* region the fusion line between the two elements is represented by a groove on the ala.

Pedicles spring from the upper half of the sides of the bodies; vertebral notches occupy the lower half. *Intervertebral foramina* increase in size from above downwards. (*Figs: 17, 18.*)

Laminae overlap markedly in the thoracic region and slightly in the cervical region. In the lumbar region there are *interlaminar gaps*; so there are in the cervical region when the neck is bent. The largest gaps are between skull and atlas, atlas and axis, fourth and fifth lumbar vertebrae, and fifth lumbar vertebra and sacrum.

Vertebral Foramina and the Vertebral Canal. In the thoracic region the vertebral canal is circular and of the diameter of a signet ring, circular because the spinal cord is here cylindrical; but in the

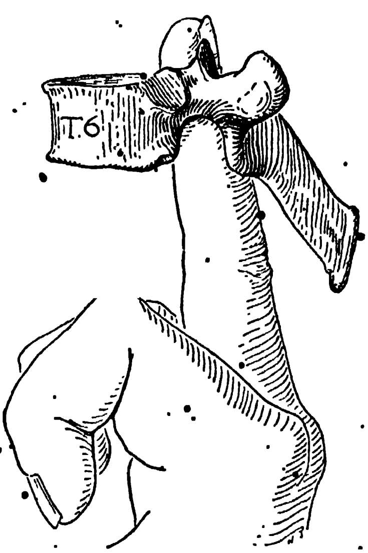


FIG. 29. A vertebral foramen is not larger than a finger-ring.

regions that lodge the brachial and lumbar enlargements the canal is larger and triangular, or rather it is expanded transversely in adaptation to the more laterally expanded cord. Hence, when exposing the spinal cord, both the student in the dissecting room and the surgeon in the operating room must be careful to make the saw-cuts converge on a canal no larger than a finger (*fig. 29*).

In the upper three cervical vertebrae, the vertebral canal is very roomy—so roomy that free movement between the

head and the neck does not constrict the spinal cord.

Articular Processes. The *cervical* processes allow movements of flexion, extension, and looking sideways upwards, because their upper facets face obliquely upwards and backwards. The *thoracic* processes allow rotation, because they are set vertically on the arc of a circle (*fig. 514*). The *lumbar* processes allow flexion. They change direction progressively from above downwards: the inferior processes of L. 1 facing laterally, of L. 5 forwards. The articular processes prevent the bodies from slipping forwards.

Spinous Processes. The spinous processes become more massive as they are followed from higher to lower levels. The pull on each, as in rising from the stooping posture, is mainly a caudalward one; hence, each is directed caudalwards. That of the 1st *cervical* is reduced to a mere tubercle, which is turned not downwards but upwards. Were there a long spine here, to throw the head back would not be possible. It is upturned because the only muscle attached to it passes upwards to the occipital bone. The Multifidus does not extend upwards beyond the spine of the axis, and, so, leaves the atlas full freedom to rotate. In modern man, cervical spines 2–6 are bifid. The 7th ends in a tubercle and is prominent, but not so prominent as the 1st thoracic. In the *thoracic* region the middle four spines—those behind the pericardium—are markedly overlapping (*figs. 512, 517*). The 1st and 2nd, and the 11th and 12th are nearly horizontal. The *lumbar* spines are thick oblong plates with thickened ends. The *sacral* spines and laminae are absent below the third or fourth, and the articular processes form an irregular crest ending below in cornua, which articulate with the cornua of the coccyx.

MUSCLES

It is from the fancied resemblance certain muscles bear to mice, the tendons presumably being their tails, that the diminutive term "muscle" is derived (L. mus = a mouse).

There are three types of muscle: (1) *skeletal* or voluntary, such as those of the limbs, body wall, and face, (2) *heart* or cardiac, which is confined to the heart, and (3) *smooth*, visceral, or involuntary, such as is found in the stomach, bladder, and blood vessels.

Skeletal muscles are under the control of the will; hence, they are alternatively called voluntary muscles. Histologically they possess light and dark cross-striations. Heart muscle also is striated, but neither heart muscle nor smooth muscle is under voluntary control; they are both involuntary. The accompanying table indicates that the terms striated and involuntary are comprehensive.

APPEARANCE	RESTRICTIVE NAME	
striated	skeletal	or voluntary
	heart	involuntary
nonstriated	or smooth	

To contract and to relax is the function of all three types of muscle. Skeletal or voluntary muscles mostly pass from one bone across a joint (or joints) to another bone, and by contracting they approximate their sites of attachment; hence, they act upon joints. Heart muscle and smooth muscle mostly form the walls of cavities and tubes, and by contracting they expel the contents.

The distinction between voluntary and smooth muscle on the basis of their

ability to be controlled by the will is not always clear. Thus, the diaphragm is structurally a voluntary muscle like the Biceps, and though it can be controlled voluntarily, as on taking a deep breath or on holding the breath, ordinarily it works involuntarily. Again, the upper part of the oesophagus is supplied with voluntary muscle and the lower part with smooth, yet voluntary control cannot be exercised over either part. Further, certain varieties of bivalve molluscs control the closure of their shells by smooth muscle; others by voluntary muscle. The latter are able by rapidly closing their shells to propel themselves through the water; those with smooth muscle cannot so propel themselves. Hence, it would appear that the distribution of voluntary and smooth muscle is determined not so much by the type of control required as by the character of the contraction required—voluntary (skeletal) muscle having the property of rapid contraction; smooth muscle, of slow sustained contraction without fatigue. Carey, indeed, believed he has been able to convert the nonstriated smooth muscle of the dog's bladder into striated muscle.

Skeletal or Voluntary Muscle is the subject of the remainder of this section. The red or lean of a roast of beef is voluntary muscle. Voluntary muscles form about 42 per cent of the total body-weight. They are the engines or motors of the body. When they contract, by bringing two bony points closer together, they act on joints, producing movement. Of the energy set free in this process only a small percentage (20%) appears as work, the remainder as heat. If shortening is prevented (e.g., as when endeavouring to lift too heavy a load) then all the energy is made manifest as heat; so, muscles are also the furnaces of the body.

Structure. The "fibres" of a voluntary muscle are in reality cells consisting of protoplasm or sarcoplasm, several nuclei, and a cell membrane, the *sarcolemma* (Gk. sarx = flesh; lemma = a husk or skin; cf. sarcophagus, sarcoma), and through the sarcoplasm run fibrils. The fibres range from about 1 mm. to 41 mm. in length. Around each individual fibre there is some loose areolar tissue (endomysium), around a collection of fibres there is more (perimysium), and around the entire muscle still more (the muscle sheath). This areolar tissue permits swelling, gliding and, indeed, independent action of the enclosed fibre or collection of fibres. In a length of muscle, such as the Sartorius, many fibres are arranged more or less end to end. Regarded macroscopically such a chain of fibres is commonly referred to as a fibre, which, in a functional sense, it is.

In some animals muscle fibres are *red*, or *dark*, as in the leg of a chicken; others are *white* or *pale*, as in the breast. In man, red and white fibres are mixed in different proportions in different muscles. The red have a smaller diameter than the white, more sarcoplasm, a poorer cross-striation and a better longitudinal striation. In general, slowly contracting but constantly active muscles are mainly red e.g., diaphragm, eye muscles, muscles of mastication; rapidly contracting but readily exhausted muscles are mainly white. Flexor muscles are mainly white, extensors mainly red; but the Gastrocnemius is largely white, the Soleus largely red.

Exceptions. Though voluntary muscles typically cross at least one joint and are attached at both ends to bone, the attachment is commonly in part via the medium of deep fascia, intermuscular

septa, interosseous membranes, or ligaments, which being fibrous will not stretch. But certain voluntary muscles, particularly those of the face, are by one end attached to *skin*—through them we express our emotions; others, articular muscles, are by one end attached to the synovial capsules of joints—an *articular muscle*, by withdrawing the capsule saves it from being nipped; still others form rings or *sphincters* around the entrance to the orbital cavity, mouth, and anal canal—

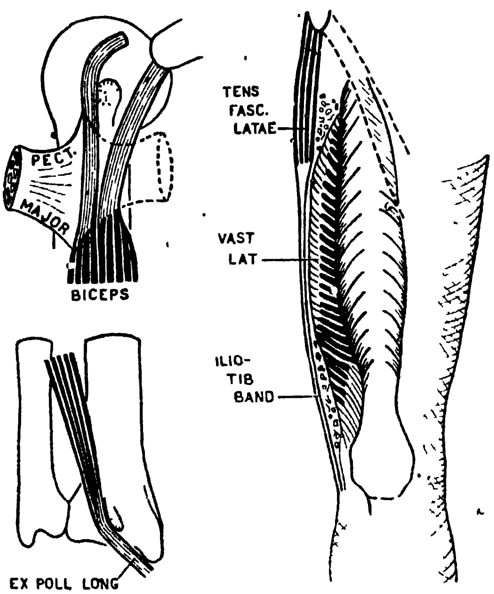


Fig. 30. Three examples of a principle: where a muscle is subjected to pressure its fleshy fibres are replaced by tendon or aponeurosis.

these close the eyelids, lips, and anus respectively. The *constrictors* of the pharynx constitute what practically is a tubular muscle; the voluntary muscle of the oesophagus actually is tubular. The Transversus Abdominis and the diaphragm are constrictors or compressors of the abdominal contents.

The Parts of a Muscle. The proximal attachment of a limb muscle is called the *origin*, and the distal attachment the *insertion*, for reasons given on page XVIII. The fleshy part of a muscle is sometimes referred to as the *fleshy belly*, the origin as the *head*, and the insertion as the *tail*. Some muscles are fleshy from end to end, but most are fibrous at one end or at both. The fibrous end has the same histological structure as ligament. When rounded it is called a *tendon*, when flattened and membranous, an *aponeurosis*, which suggests that it is nervous—but the ancients did not distinguish between nerves, ligaments, and tendinous structures. The fibrous end is continuous with the endo- and peri-mysium, and it is by some believed that the fibrils of the muscle fibres also continue through the tendon as collagenous fibres.

The two chief component parts of a voluntary muscle, then, are (1) the fleshy and (2) the fibrous (tendon or aponeurosis). These have contrasting properties: *fleshy fibres* are highly specialised, contractile, vascular, expensive in upkeep, and resistant to infection, but they cannot survive pressure or friction; *tendons* are unspecialised, inelastic, non-vascular, and inexpensive in upkeep. They are designed to withstand pressure, but owing to their meagre blood supply they readily die (slough) when exposed to infection. Where a muscle presses on bone, ligament, tendon, or other unyielding structure, the fleshy fibres always give place to tendon (*fig. 30*). Further, if the tendon is subjected to friction, a lubricating device—a bursa or a synovial sheath—is always interposed.

It is a matter of common observation that the cross-sectional area of the tendon of a muscle is much less than that of the fleshy belly. Hence, a muscle that arises by fleshy fibres and is inserted by tendon has a much more extensive origin than insertion. Hence, the precise site of attachment of a tendon—where the force

of a muscle-pull is concentrated and focused—is of much greater practical importance than that of a wide spread fleshy attachment. At fleshy attachments forces are dissipated and make no mark on the bone, but at tendinous attachments forces are concentrated and do. Thus, tendinous attachments create ridges, tubercles, and facets, and if large they may produce traction epiphyses. Tendons are immensely strong; it is estimated that a tendon whose cross-sectional area is one inch square is capable of supporting a weight of from 9,700 to 18,000 lbs. (Cronkite). The fibres of a tendon are not strictly parallel, but plaited; they twine about each other in such a manner that fibres from any given point at the fleshy end of the tendon are represented at all points at the insertional end (*fig. 31-A*); hence, the pull of the whole muscle can be transmitted to any part of the insertion. The fan-shaped manner in which most tendons are inserted into bone ensures that successive parts of the insertion shall take the full pull of the muscle as the angle of the joint changes (*fig. 31-B, C*). There is, therefore, no necessity for the tendon to play to and fro and become frayed at the junction of its mobile and fixed parts—for the fibres of the tendon are carried into the bone, there to contribute to the formation of the bony trabeculae.

Insertions. Muscles are usually inserted near the proximal end of a bone (or lever), close around a joint, close to an axis of movement (e.g., Biceps, Brachialis, and Triceps at the elbow). So, they help to retain in apposition the ends of the bones taking part in the joint, and thereby give it strength. By being thus inserted they produce, on contracting, rapid movement of the distal end. Were they inserted towards the distal end, the movement produced would be more powerful, but it also would be slower.

Some muscles are inserted near the middle of the shaft of a bone (e.g., Deltoid, Coraco-brachialis, Pronator Teres, Adductors of the thigh) and a few are inserted near the distal end (e.g. Brachio-radialis, part of Adductor Magnus).

A Bursa (L. bursa = a purse) is a closed sac differentiated out of areolar tissue. It is roughly the size and shape of a coin. Its delicate walls are separated from each other merely by a film of slippery fluid, like white of egg. As a lubricating device, diminishing friction and allowing of free movement, a bursa is more effective than areolar tissue.

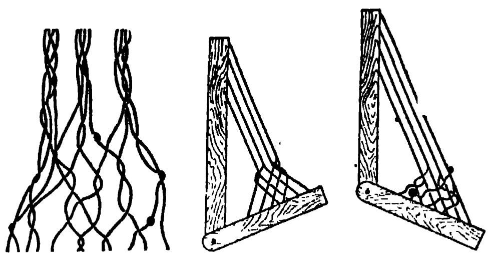


FIG. 31. A. The fibres of a tendon are plaited. B and C. In different positions of a joint different fibres take the strain. (After Mollier.)

Bursae may be classified thus—subtendinous, articular, and subcutaneous.

Subtendinous bursae are found wherever tendons rub against resistant structures, such as bone, cartilage, ligament, or other tendons; hence, they are particularly numerous in the limbs (*fig. 112*).

"*Articular*" *bursae* play the part of joint cavities, e.g., between the dens of the axis and the transverse ligament of the atlas (*figs. 699, 700*); between adjacent metacarpo-phalangeal (and metatarso-phalangeal) joints where they separate neighbouring capsules; and here may be included the subacromial bursa (*fig. 171*).

Subcutaneous bursae (p. 75).

A Synovial Sheath (mucous sheath) is a tubular bursa that envelops a tendon. In fact, it is two tubes, one within the other. The inner or *visceral tube* adheres closely to the tendon and is separated from the outer or *parietal tube* by the synovial cavity. The visceral and parietal tubes are united longitudinally, along the surface least subjected to pressure, by a synovial fold, the *mesotendon*, which transmits vessels to the tendon (*fig 32*). If the range of movement of the tendon is considerable, the mesotendon may disappear (e.g., Peronei Longus et Brevis) or be represented by threads, *vincula* (e.g., long digital flexors).

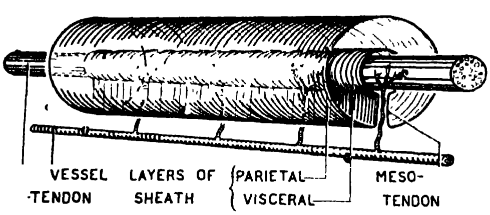


FIG. 32. Diagram of a synovial sheath.

A synovial sheath is required only where a tendon is subjected to friction or pressure on two or more surfaces (front and back). This condition obtains only at the hand and foot and in the bicipital groove at the shoulder. In all instances it so happens that the friction results from the presence of bone on one surface and of a retinacular ligament on the other. In order to allow ample play such sheaths extend about ½″ above and below the sites of friction. Synovial fluid is like bursal fluid.

Architecture or Internal Structure. The fleshy fibres of a muscle may be disposed either (1) parallel to the long axis of the muscle, or (2) obliquely, like the barbs of a feather.

The functional differences between the parallel and the oblique type is this: the parallel type has long fibres (or chains of fibres) but relatively few of them, therefore it can lift a light weight through a long distance; the oblique type has short fibres but they are very numerous, therefore it can lift a heavy weight through a short distance.

(1) FIBRES PARALLEL TO THE LONG AXIS OF THE MUSCLE or approximately so. Here the fibres may be *parallel* from end to end, perhaps having a short tendon or aponeurosis at one end or at both ends. This includes many strap-like and flat muscles (e.g., Sterno-mastoid, infrahyoid muscles, Rhomboids, Rectus Abdominis, Quadratus Lumborum, Gluteus Maximus, Sartorius). Here may be included *triangular muscles* whose fibres, though not exactly parallel, run a straight course from origin to insertion (e.g., Serratus Anterior, Pectoralis Major, Latissimus Dorsi, Anconeus, Adductores Longus et Brevis, Popliteus) and also the *fusiform type*, which has a tendon at each end (e.g., Biceps Brachii, Semitendinosus).

(2) FIBRES OBLIQUE TO THE LONG AXIS OF THE MUSCLE (*fig. 33*). From their resemblance to feathers these muscles are called *pennate*, the fleshy fibres corresponding to the barbs of the feather and the tendon to the shaft—for they are all inserted by tendon. They are (a) *unipennate* when the fleshy fibres have a linear or narrow origin (e.g., Ex. Digitorum Longus, Peroneus Tertius), for in this case the appearance is that of one half of a feather; (b) *bipennate* when the fleshy fibres arise from a long broad surface (e.g., Peroneus Longus, Fl. Hallucis Longus), for in this case the appearance is that of a whole feather; (c) *multipennate* when septa extend into the origin and insertion (e.g., Deltoideus, Subscapularis, *fig. 83*), for in this case the appearance is that of many feathers; and finally, muscles (such as the Tibialis

Anterior) whose fibres converge on a tendon which extends into their substance, may be spoken of as "*circumpennate*".

Note that a bipennate muscle arises not only from two lines but also from the surface between those lines; hence, it is many times more powerful than a unipennate muscle. Multipennate and "circumpennate" muscles are correspondingly still more powerful.

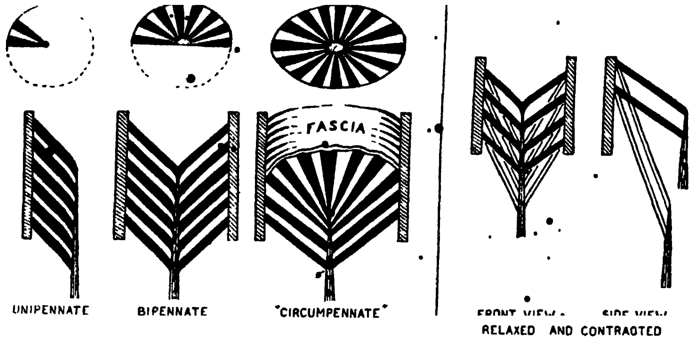


FIG. 33. Diagrams showing the architecture or internal structure of pennate muscles. Pennate muscles, obviously, are powerful muscles. (After Pfuhl.)

Contraction. When muscle fibres contract or shorten they necessarily increase in circumference (*fig. 34*)—they swell, as exemplified in gross form by the Biceps Brachii in changing from its relaxed to its contracted state. In pennate muscles the side or upward thrust imparted by each swelling fibre to its neighbour is no negligible factor in raising the tendon during the contraction of the muscle.

On contracting, the fleshy fibres of a muscle shorten between a third and a half (57%, Haines) of their resting length. Being, so to speak, expensive in upkeep they are never longer than necessary—those of a muscle composed of parallel fibres being two or three times the length of the distance through which the site of insertion can move. If the distance between origin and insertion is greater than the length of fibre required for full action, the surplus length is fibrous, i.e., tendinous or aponeurotic, (e.g., Sartorius p. 383; Rectus Femoris p. 388). A tendon can be any length. As a corollary, knowing the range of movement of the bony point into which a muscle is inserted, the length of the fleshy fibres (or chains of fibres) of that muscle can usually be calculated, and the most distal point possible for its origin established (example: Biceps Femoris p. 404). The various fleshy fibres (or chains of fibres) of a parallel or an oblique-fibred muscle have equal work to do, and so are equal in length; therefore, one can usually reason out the aspect of the muscle on which the tendon appears, for this must be on the opposite surface from the origin (e.g., Fl. Digitorum Profundus, *fig. 112;* Fl. Pollicis Longus, *fig. 113*).

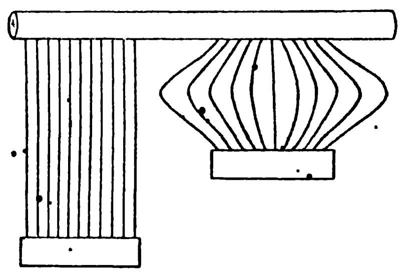


FIG. 34. On contracting, fleshy fibres shorten to between ⅓ and ½ of their resting length and swell correspondingly.

The fleshy fibres of a triangular muscle whose base is inserted into a limb bone (e.g., Anconeus at the elbow, Pectineus and Adductor Longus at the hip) are longer on the distal side than on the proximal. They require to be so, because the most distal point of insertion makes the greatest excursion.

Investigation. In investigating the action of muscles five methods are available: (1) In the cadaver a muscle may be freed from surrounding structures and pulled upon, and the resultant position of the joints upon which it acts taken to indicate the actions of the muscle in life.

(2) In the living subject a muscle may be stimulated to contract by the suitable application of the electrodes of an induction coil to the skin, one being placed over the motor point (p. 30) of the muscle. This was Duchenne's method of approach, and his work forms the basis of our knowledge of this subject.

(3) A living person may be instructed to execute a specified movement while an observer, by inspection and palpation of the muscles of the region, determines which are in action. Precautions must be taken to avoid confusing antagonists and synergists with prime movers (p. 29).

(4) Clinical information may be gained from the study of the effects (a) of nerve injuries—and these were plentiful during the war—and (b) of transplanting tendons surgically in cases of paralysis. These fall into the category of experiments performed accidentally and by design.

(5) Inman, Saunders, and Abbott have recently developed a new method which would seem to be the ultimate, or at least the penultimate, method. It consists in planting electrodes in the muscle of a living human subject, and having him perform a motion. The differences in the electrical action potentials of the muscle are amplified and recorded mechanically. Now, it has been determined that there is a direct relationship between the tension developed in a muscle and the action current potential; so, by this procedure one can analyse the activity of an individual muscle during motion, noting, for example, during what stage of a movement it comes into action and during what stage it exhibits its greatest activity. Further, by using a number of amplifiers the simultaneous actions of a group of muscles can be studied (p. 185).

Methods nos. 1 and 2 give information as to what an individual muscle acting alone would do. Since, however, instances of a muscle acting singly are few (e.g., closing the eye), these have less practical importance than methods nos. 3 and 4. Method no. 5 may be expected to throw on the subject a light that will illuminate many obscure features and reveal errors in our present teaching.

Muscle Action. A neurone and the muscle fibres it controls, generally about 100, may be called a *"motor unit"* much as one may speak of a kidney, a liver, a spleen, or a lung unit. Only a small proportion of motor units are in action at a given moment, at least they are in different phases of activity, because impulses are discharged by the central nervous system asynchronously.

While maintaining a given position or posture the muscles concerned are in a state of reflex contraction or *tone.* Tone depends on the afferent impulses reaching the brain from the sensory endings in muscles, tendons, and joints—also on the state of the vestibular apparatus and of the central nervous system. Under anaesthesia tone is abolished; hence, dislocated joints are more easily reduced under an anaesthetic which abolishes the exag-

gerated tone called spasm. Differences in tone depend upon the rate at which impulses are discharged in a given unit and upon the number of units in play. *Movements* are produced by throwing an increasing number of motor units into action and at the same time diminishing the tone of the antagonistic muscles (i.e., reflex relaxation).

Most bodily actions, even ordinary ones, call into play principal muscles and many assistants. The principal muscles, *prime movers* or agonists, by actively contracting (shortening) produce the desired movement. The muscles that produce the opposite movement, *antagonists*, by actively relaxing or "paying out" cause to be smooth and regulated a motion that otherwise would be jerky and spasmodic. In a sense, the two ropes of the rudder of a boat act as prime mover and antagonist; and when the cox pulls on the one, he does not let the other become slack. Again, when a prime mover passes over more than one joint, certain muscles are called upon to steady the intervening joints; such muscles are *synergists* (Gk. syn = together; ergon = work). Still other muscles, *fixators*, are called upon to steady the more proximal parts of the limb or trunk. Obviously, the same muscle may act as prime mover, antagonist, synergist or fixator under different circumstances.

Examples. (1) When you lay your hand and forearm on the table and abduct your thumb, not only is the Abductor Pollicis Longus (at the lateral border of the wrist) felt to become taut but also the Flexor and Extensor Carpi Ulnaris—the medial edge of the former is felt on deep pressure just proximal to the pisiform, of the latter just proximal to the base of metacarpal V. These two ulnar muscles act as synergists; they fix the wrist joint lest it too be abducted.

(2) The long flexors of the fingers flex the interphalangeal and metacarpophalangeal joints and also the wrist joint. Now, on clenching the fist or on closing the hand, say on a broom handle, the tendons of the Extensores Carpi Radiales and Ulnaris can be felt to contract (see p. 147). They do so in order to prevent flexion of the wrist; they act as synergists.

(3) On flexing the interphalangeal joints, as on gripping a golf club, the Extensor Digitorum Communis is felt to contract, as a synergist, to prevent flexion of the metacarpo-phalangeal joints.

Resistance may be a substitute for an antagonist. Example: If your elbow is rigidly flexed at a right angle, both your Biceps and Triceps can be felt to be contracted. If now you place your palm under the edge of a heavy table and make an effort to raise it, the Triceps is felt at once to relax, demonstrating that the resistance of the table replaces the action of the Triceps.

Gravity is a valuable aid to some movements, depending upon the position of the limb or of the body. Example: On raising the arm from the side, the multipennate portion of the Deltoid (*fig. 83*) is the prime mover; gravity (certainly if there is a weight in the hand) is a sufficient antagonist; the anterior and posterior long fibres of the Deltoid act as synergists; the Trapezius and Serratus Anterior fix the shoulder girdle (*fig. 164*) and, so, become fixation muscles—in fact, without them nothing would be achieved. On lowering the arm, gravity becomes the prime mover and the Deltoid the antagonist. If resistance is encountered, as on pressing the hand downwards on the table, the anterior and posterior folds of the axilla become taut because the Pectoral muscles and the Latissimus Dorsi come into play as prime

movers, and the Deltoid relaxes. Similarly, in walking the raised limb tends of its own weight to fall to the ground.

When the flexed elbow is relaxed, it is gravity, not the Triceps, that as a rule causes the hand to fall to the side. Indeed, the common use of the Triceps is not to extend the elbow but to prevent the elbow from flexing, as in pushing a wheelbarrow. When the hand is raised above the head, however, as in brushing the hair, also in the back stroke in tennis etc. the Triceps is a prime mover.

Blood Supply. The chief vessels enter a muscle with the nerve; accessory vessels unaccompanied by nerves are present in many muscles. The vessels in a muscle anastomose to form a rectangular network. The veins in the muscles, like those in the limbs in general, have valves; so, muscular exercise, by massaging these veins, aids in circulating the blood.

LYMPH VESSELS run with the blood vessels.

Nerve Supply. The nerve to a muscle, though called a motor nerve, is in reality a mixed nerve, being about $\frac{3}{5}$ motor, $\frac{2}{5}$ sensory, and partly sympathetic. (1) The motor (efferent) fibres pass to *motor end-plates* (i.e., areas of granular, nucleated sarcoplasm under the sarcolemma in which a nerve fibril branches like an open hand). (2) The sensory (afferent) fibres begin as. (a) *free endings* on the muscle fibres, as (b) *encapsuled endings* in the connective tissue, and as (c) *muscle spindles* -these are spindle-shaped swellings 1 to 4 mm long, having a laminated areolar capsule containing some fluid. Passing longitudinally through this are several thin and poorly developed voluntary muscle fibres, supplied with motor end-plates. Sensory nerve fibres pass to these muscle fibres and either spread over them, or form rings or spirals around them. Similar sensory endings are found in tendons, but in tendon spindles collagen fibres substitute for muscle fibres. It is through the sensory nerves in muscles, tendons, and joints that one is kept informed of the position of the parts of one's body in space; so, even with the eyes shut or in the dark, one can walk without stumbling, feed oneself without spilling, and shave without a mirror; further, one knows whether a joint is extended or, if flexed, the degree. (3) The sympathetic fibres are, by some, believed to end in the muscle fibres, but, by most, to supply the vessels (Wilkinson).

Most motor nerves are derived from more than one spinal segment, and the segments are always consecutive (e.g , C. 5,6, or L. 2,3,4). Muscles placed near the surface of the body may be made to contract on applying an electrode to the skin near the point of entry of the nerve. The appropriate point for each muscle is called the *motor point* of that muscle.

Nomenclature. The names given to muscles are descriptive of their *geometrical shape* (e.g., Triangularis, Trapezius, Rhomboidei, Teres Major, Quadratus Femoris); of their *general form* (e.g., Longus Capitis, Serratus Anterior, Latissimus Dorsi, Piriformis, Gracilis, Vasti); of the number of *heads* or *bellies* (e.g., Biceps, Triceps, Quadriceps, Digastric); of their *structure* (e.g., Semitendinosus, Semimembranosus); of their *location* (e.g., Temporalis, Supraspinatus, Intercostales, Iliacus, Tibialis Anterior); of their *attachments* (e.g., Stylo-hyoideus, Ilio-costalis, Brachio-radialis); of their *action* (e.g., Flexor and Extensor Carpi Ulnaris, Abductor and Adductor Digiti Quinti, Levator Scapulae, Depressor Anguli Oris, Supinator, Pronator Teres, Rotatores, Tensor Palati); of their *direction* (e.g., Rectus Abdominis, Obliquus Oculi Superior, Transversus Linguae); of *contrasting*

features (e.g., Pectoralis Major and Minor, Peroneus Longus and Brevis, Pterygoideus Medialis and Lateralis, Tibialis Anterior and Posterior, Gemellus Superior and Inferior, Obturator Internus and Externus; Gluteus Maximus, Medius and Minimus; Vastus Medialis, Intermedius and Lateralis). There being, then, a fairly obvious reason for the name of each muscle, the student should rarely forget or confuse them.

Variations. Muscles are subject to variation, and books have been written about their variations. The muscles that vary most are muscles that are either "coming" or "going", that is, muscles that are appearing in the species and muscles that are disappearing:—the Palmaris Longus and Plantaris are disappearing (the one is absent in 13.7% of 461 limbs, the other in 6.8% of 528 limbs) and when present the sites of origin and insertion and the size of the fleshy bellies vary greatly. The Peroneus Tertius is appearing (it is absent in 6.9% of 360 limbs) and when present it is inserted anywhere along the dorsum of metatarsals 3, 4, or 5 or to the interosseous membrane between them. The Peroneus Longus has migrated across the sole of the foot to be attached to metatarsal 1. In 72.3% of 213 limbs it is attached also to cuneiform 1, and in 48.3% to metatarsal 2 also. The short muscles to the little finger and little toe are commonly in part suppressed.

It is obvious that the wide-spread fleshy origin of a muscle may spread either a little more or a little less without affecting the action of the muscle (e.g., the Pectoralis Minor, typically arising from ribs 3, 4, and 5, may extend upwards to the 2nd rib or downwards to the 6th; on the other hand, the lower portions of the Trapezius and Pectoralis Major are not uncommonly wanting). Equally obviously, the strictly localised site of insertion of a tendon can seldom be displaced without altering the action of the muscle.

Accessory or Supernumerary Muscles mostly lend themselves to explanation on morphological grounds; they are not clinically important. The Sternalis and the Axillary Arch are of considerable interest (q.v.). Sometimes the Biceps Brachii has three origins and the Coracobrachialis three insertions, as in some primates, and occasionally they have four.

All these conditions being present at birth, the subject adjusts himself to them.

THE BLOOD VASCULAR AND LYMPHATIC SYSTEMS

The blood vascular system comprises (a) the heart and (b) the blood vessels (arteries—capillaries—veins). These form a tubular system which with few exceptions is closed, lined throughout with endothelial cells, and filled with blood. It receives the lymph and chyle brought to it from the lymphatic system. These two allied systems—the blood vascular and lymph vascular—constitute the circulatory system.

Blood. The volume of blood in the body is about 10 pints, and it equals about $\frac{1}{11}$ of the total body-weight. It is composed of plasma and cells. The *plasma* or fluid portion of the blood = 91% water and 9% solids (e.g. proteins, salts, products of digestion and waste products), also respiratory gases (O_2 and CO_2), internal secretions, enzymes, etc. The *cells* = red corpuscles (erythrocytes), white corpuscles (leucocytes) and blood platelets (thrombocytes); these are in suspension.

Animals, like plants, absorb their food in fluid form. The fluid products of digestion are absorbed from the digestive

tract into the blood-stream for distribution to the various tissues and organs of the body for their growth, maintenance, and diverse activities (e.g., contraction in muscles, secretion in glands). Oxygen from the air passes into the lungs and thence into the blood-stream, the plasma dissolving a small amount, the red cells

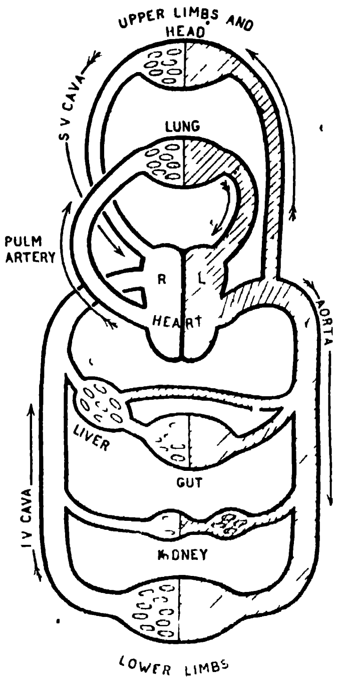


FIG. 35. Diagram of the circulatory system. Hatched vessels conduct oxygenated blood; clear vessels conduct blood laden with carbon dioxide. Note the pulmonary and systemic circuits and the double set of capillaries on the subsidiary digestive and renal circuits.

combining with 60 times as much This also is distributed to the tissues. The waste products of metabolism formed in the tissues, enter the blood-stream and are brought by it to the excretory organs (kidneys, bowel, lungs, and skin). It is through the capillaries that these various interchanges take place.

Definitions. The *heart* is a hollow muscular pump. Its duty is to pump the blood to the capillaries. *Capillaries* are tubes whose walls consist of thin semipermeable membranes—permeable to water and crystalloids, but impermeable to the proteins of the blood plasma and to other substances of large molecular composition. Through them nutritive materials and O_2 pass from the blood to the tissues; and through them waste products and CO_2 return from the tissues to the blood. *Arteries* are tubes that conduct blood from the heart to the semipermeable capillaries. *Veins* are tubes that conduct it back from the semipermeable capillaries to the heart.

The Circulation of the Blood. The blood traverses two separate circuits, (*fig.* 35), the *pulmonary* and the *systemic*, each with its own pump:

(1) The right side of the heart pumps the blood through the vessels of the lungs- these constitute the pulmonary or lesser circuit.

(2) The left side of the heart pumps the blood through the vessels of the body generally—these constitute the systemic or greater circuit.

To serve these two circuits, the heart has four chambers, two on the right side and two on the left. One of these on each side is a thin-walled receiving chamber, the *atrium*, the other is a thick-walled distributing or pumping chamber, the *ventricle*. *The Pulmonary Circuit:* The blood entering the right atrium (via the s. v. cava, i. v. cava, and veins of the heart itself) passes to the right ventricle which pumps it through the pulmonary arteries to the capillaries of the lungs, thence through the pulmonary veins to the left atrium. *The Systemic Circuit:* From the left atrium the blood passes to the left ventricle which pumps it through the aorta and its various arterial branches to the capillaries

of all the rest of the body, thence through veins which become increasingly larger and fewer till finally the superior and inferior venae cavae and the cardiac veins return to the right atrium the same volume of blood as the left ventricle ejects into the aorta, and at the same rate.

Normally blood is red when the oxygen content is high and blue when it is low. Oxygen is taken up by the capillaries in the lung and carbon dioxide is given off. The reverse process occurs in the systemic capillaries. It follows, therefore, that blood is *red* in the pulmonary veins, left side of the heart, and systemic arteries; and *blue* in the systemic veins, right side of the heart, and pulmonary arteries. It is customary in illustrations to colour the parts red and blue accordingly.

Though the capacity of each of the four heart chambers is practically the same (60–70 cc.), the resistance offered by the pulmonary vessels is obviously much less than that offered by the systemic ones; accordingly, the wall of the right ventricle is much thinner than that of the left.

STRUCTURE OF THE HEART WALL. The chief part of the heart wall is the muscle, the *myocardium*. It consists of oblong cells, transversely striated, each with a centrally placed nucleus. Having no sheath (sarcolemma) the cells are enabled to join end to end and to be connected by side branches, so they form a syncytium (Gk. syn = together; cytos = a cell). Internally the myocardium is lined with a layer of endothelial cells, the *endocardium*, continuous with that of the blood vessels and resting on a meagre sub-endocardial areolar layer. Externally it is covered with a similar layer of cells, the *epicardium* (visceral pericardium), which rests on a thin subserous areolar layer. In the latter run the main cardiac vessels often embedded in much fat. For heart valves, see pp. 541, 551.

Blood Vessels (arteries, capillaries, veins). The main systemic artery (the *aorta*) and the *pulmonary artery*, each about 30 mm. in diameter, branch and rebranch like a tree, the branches becoming smaller as they become progressively more numerous. When reduced to a diameter of about 0.3 mm. and just visible to the naked eye they are called *arterioles*. These break up into a number of *capillaries* (L. capillus = a hair), each about ½–1 mm. long and large enough (7 μ or more) to allow the passage of the red blood cells in single file. The capillaries form an anastomosing network or rete. The cross-sectional area of the entire systemic rete or capillary bed is about 800 times greater than that of the aorta. In this rete the smallest veins, called *venules*, have their source. Veins accompany arteries and have the same tree-like pattern as arteries but, owing to the direction of the blood-current within them, they are usually likened not to trees but to rivers, the branches being called *tributaries*.

Below the elbow and knee, and elsewhere, arteries are closely accompanied by paired veins, *venae comitantes* (comites), one on each side. These veins are united to each other by short branches which form a network around their artery. The pulsations of the artery, by indenting the veins, perhaps aid slightly in forcing the venous blood onwards towards the heart. Veins also run independently of arteries (e.g., superficial veins); veins are more numerous than arteries and their calibre is greater.

Veins characteristically have folds of the inner tunic, called *valves*, generally with two cusps and commonly placed immediately peripheral to the mouth

of an entering tributary. Like the gates of a canal-lock, they open in one direction, namely, towards the heart. Around the valve the wall of the vein is dilated, as at the aortic valve (*fig. 569*), to allow back eddies to close the cusps.

The venous valves nearest the heart are placed near the ends of the internal jugular, subclavian, and femoral veins

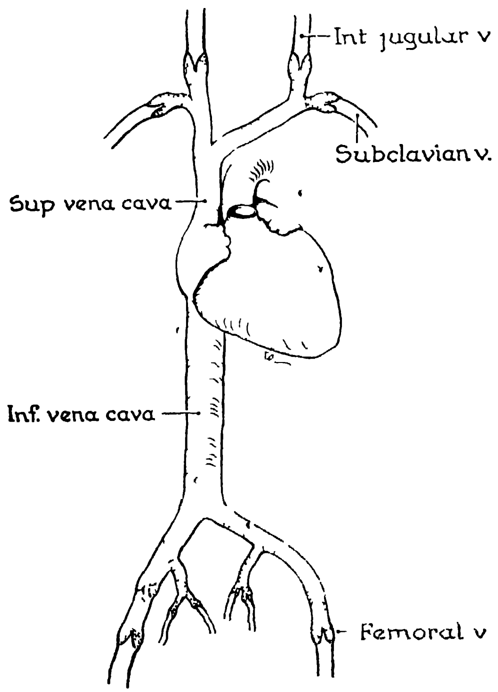


FIG. 36. The venous blood is imprisoned in the trunk by valves.

(sometimes in the common and external iliac veins) (*fig. 36*). Thus, they imprison the venous blood within the trunk, and during periods of increased intra-abdominal pressure (e.g., during defaecation) and during increased intrathoracic pressure (e.g., during expiration), they prevent it from being forced back into the limbs, head, and neck. There are no functioning valves in the portal system, and only rarely do those (2 or 3) in the cardiac veins function. Valves are most numerous in the veins of the limbs. They are readily demonstrated in the superficial veins of the forearm thus: Circumduct your limb vigorously at the shoulder joint in order to cause the veins to fill; then, keeping the forearm below the level of the heart so that the veins shall not empty, with the tip of your index obstruct a prominent vein about the middle of the forearm and, by stroking proximally with your thumbnail, empty a long segment of the vein. Note that on removing the thumb the vein fills from above as far as the nearest

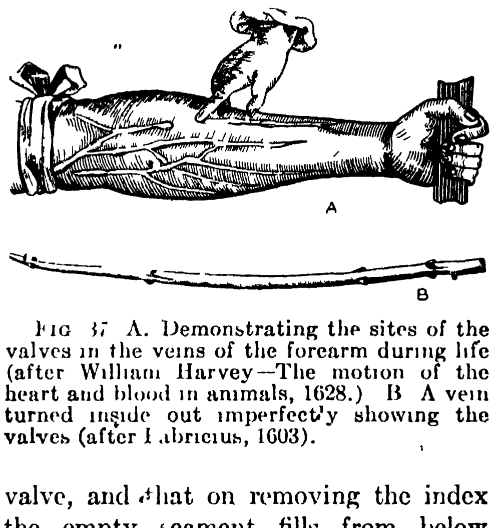


FIG 37 A. Demonstrating the sites of the valves in the veins of the forearm during life (after William Harvey—The motion of the heart and blood in animals, 1628.) B A vein turned inside out imperfectly showing the valves (after Fabricius, 1603).

valve, and that on removing the index the empty segment fills from below (*fig. 37*).

The veins of the limbs are elliptical on cross-section, the long axis of the ellipse being parallel to the overlying skin. This is notably the case at the sites of valves (*fig. 38*). The two cusps of each valve arise from the long curves of the ellipse; hence, when the valve is compressed, e.g., between the skin and the deep fascia, its function is not impaired. The same is true of unicuspid valves, which, however, are much less numerous than bicuspid valves. A similar arrangement exists at the valves of the deeper seated veins,

e.g., those in the external iliac vein are parallel to the parietal peritoneum; those in the subclavian vein are parallel to the underlying first rib—and so probably for venous valves in general (E. A. Edwards).

STRUCTURE. *Arteries* typically have three coats or tunics: (1) the *tunica intima* or inner coat has a lining of endothelial cells, with a little subendothelial areolar tissue and, outside this, a tube of elastic tissue (the internal elastic membrane); (2) the *tunica media* or middle coat is composed of alternate layers of smooth muscle and elastic tissue in an areolar bedding; (3) the *tunica adventitia* or outer coat is a fibroareolar tube of considerable strength containing some elastic fibres.

Both muscle tissue and elastic tissue are elastic, like rubber, and after being stretched they tend to return to normal length, i.e., they contract passively. Muscles can also contract actively; elastic tissue cannot. Hence, muscle requires a large blood supply; elastic tissue requires but little. Elastic tissue is a muscle sparer; its upkeep is inexpensive.

The blood ejected at each heart beat into the aorta causes it to expand—to become temporarily a receptacle. As the expanded aorta returns to normal, it drives the blood through the arteries and arterioles into the capillary bed. The amount escaping into the capillary bed in a given region, however, is regulated by the need of the tissue at the time. In other words, the blood in the "receptacle" is apportioned to the organs in accordance with their requirements. The mechanism controlling the distribution is the muscle in the walls of the arterioles which, so to speak, can be turned on and off like a tap. The aorta and the large arteries have much elastic tissue and relatively little muscle in their walls; whereas the arterioles are essentially muscular.

Capillaries have but one coat, namely, the endothelial lining common to all vessels and the heart.

Veins have the same general structure as their companion arteries. Their calibre, however, is greater; the blood pressure within them is lower; they have less muscle and much less elastic tissue. A vein may be described as an areolar tube in which a muscle coat is embedded, and which possesses an endothelial lining. Some hours after death all the muscular tissue in the body contracts; hence, the

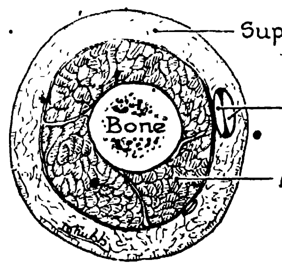


FIG. 38. Veins tend to be elliptical on cross section. The long axes of the cusps of their valves are so disposed that external pressure does not impair their function.

corpse becomes rigid (rigor mortis) and the blood is driven from the more muscular arteries into the less muscular veins. Even after the rigor passes off and the vessels relax, the arteries are empty (or contain gases of decomposition) and the veins are filled with blood. Arteries (Gk. and L. arteria = an air tube) derive their name from the fact that they were believed to be conductors of air like the trachea, which was known as the arteria aspera or rough air tube.

Vasa Vasorum. The heart wall is supplied by the coronary arteries and cardiac veins. The outer layers of arteries whose diameter is greater than 1 mm. are supplied by small vessels, *vasa vasorum*, which lie in the tunica adventitia

and extend into the media. The inner layers of the large arteries are also supplied by minute vasa vasorum whose pinpoint mouths open into the lumen of the artery.

The Distribution of the Blood and Its Nervous Regulation. The volume of blood pumped into the aorta in a given time equals that returning to the right atrium, which in turn equals that pumped into the pulmonary artery and returning to the left atrium. If it were otherwise, there would be temporary or permanent local congestions. The blood pressure within the aorta is about 120 mm. of mercury, at the arterial end of the capillaries about 30 mm., at the venous end 12 mm. and in the great veins 5 mm. This determines the direction of the blood flow. The rate of flow in the aorta, when the subject is resting, is about 0 5 metres per second, in the capillaries about 0.5 mm. per second, and in the veins it gradually increases until in the venae cavae it nearly equals the rate in the aorta.

The *heart* is supplied by efferent vagal and sympathetic fibres. Stimulation of the vagus results in slowing of the heart, stimulation of the sympathetic in acceleration. Paralysis of both vagi results in acceleration; paralysis of both sympathetics in slowing. When the blood pressure in the arteries rises, afferent fibres of the vagus distributed to the aortic arch (aortic nerve) and of the glossopharyngeal nerve distributed to the carotid sinus (sinus nerve) are stimulated and reflexly bring about slowing of the heart and vasodilatation of the vessels with consequent fall in blood pressure.

The *blood vessels*, particularly the arterioles, are supplied by efferent autonomic fibres—both vasoconstrictor and vasodilator. Excitation of the vasoconstrictors results in constriction (contraction) of the arterioles with consequent diminution in the blood supply to the part and rise in blood pressure; excitation of the vasodilators has the opposite effect. This mechanism allows the blood to be partly shut off from one part of the body and diverted to another, e.g., during digestion it is diverted to the abdominal viscera; during hot weather it is diverted to the skin so that heat may be lost.

The sympathetic nerves to the vessels of the *limbs* travel in the peripheral nerves (e.g., median, ulnar, tibial) and are distributed by them in their course. Those to the *head* and *neck* ascend in the cervical sympathetic trunk, pass to the carotid arteries, and travel along their branches. Those to the *abdominal viscera* travel via the thoracic splanchnic nerves (especially the greater splanchnic nerve) to the coeliac plexus, thence they are distributed to the branches of the abdominal aorta. Those to the *pelvic viscera* travel via the lumbar splanchnic nerves to the hypogastric plexus (presacral nerve).

Certain cranial nerves transmit a few vasodilator fibres. The pelvic splanchnic nerves transmit vasodilator fibres to the rectum, bladder, and external genitalia, and, because the consequent engorgement results in erection of the penis or clitoris, they are alternatively known as the *nervi erigentes*.

Anastomoses and Variations. During development, networks of vessels sprout into actively growing parts (e.g., organs and limbs) and, as the parts enlarge, the networks advance farther into them. Certain channels through these networks are chosen to be permanent arteries and veins and their branches; the others disappear (*fig. 421*). There being a wide choice of channels in the network, it is not surprising that those selected for

permanency should vary somewhat from individual to individual. By way of demonstrating this fact, pull up your sleeve and compare the pattern of the superficial veins on the front of your forearm with that of your neighbour; minor if not major differences will be seen; even between your right and left limbs the patterns differ.

Although the number of channels in the network retained to form main arteries is restricted, commonly to one or two, the peripheral parts persist as capillary channels and the communications between these and neighbouring capillaries are called anastomoses (i.e., furnished with stomata or mouths). Anastomoses also occur between certain large vessels (e.g., the circle of Willis at the base of the brain; the palmar arches, *fig. 136;* the intestinal arcades, *fig. 221*) and between many small vessels and precapillary vessels (e.g., around joints and in the heart). In cases of obstruction of the larger arteries, it is by the enlargement of these anastomoses that a collateral circulation is established and the vitality of distant (or neighbouring) parts preserved.

An arterial channel, which under ordinary circumstances disappears, may persist as an *accessory* or *supernumerary* artery (e.g., renal, *fig. 289-B*); if the normal artery disappears the persisting artery will act as a substitute for it (e.g., brachial, *fig. 104;* profunda, *fig. 105*). Such *abnormal* arteries, acting as substitutes, account for the erratic courses sometimes taken by certain arteries and for the unusual relationships they may bear to neighbouring nerves and other structures. The same remarks apply to veins.

The primitive zig-zag course through the network usually becomes a relatively straight one in the definitive artery, but it may be angular if side branches so anchor it, as in the case of the dorsalis pedis (*fig. 421*) and of the popliteal artery which is held laterally by the anterior tibial.

It is easily understood that arteries are *sinuous* or *tortuous* when supplying parts that are highly mobile like the cheeks and lips, protrudable like the tongue or expansile like the uterus and colon—even the nerve (optic nerve) to the movable eyeball requires to be sinuous. It is not so obvious why the splenic artery should be tortuous, while its companion vein is straight, or why the branches of the testicular artery (running on the inner surface of the inexpansile tunica albuginea) should be sinuous. In the aged the temporal artery is commonly visibly tortuous and the brachial and radial arteries can be felt to be so, owing to degenerative changes in their elastic walls.

Arterio-venous Anastomoses. In some regions arterioles communicate directly with venules, e.g., in the skin of the palm of the hand and of the terminal phalanges, in the nail bed, in the skin of the lips, nose, and eyelids and at the tip of the tongue. This is in addition to the regular communications by capillary.

End-arteries are arteries that do not anastomose with neighbouring arteries except through terminal capillaries. Obstruction of such an artery is likely to lead to local death, resulting in the case (a) of a cerebral artery, in paralysis, (b) of the central artery to the retina, in blindness, (c) of a branch of the renal or splenic artery, in death of a segment of the kidney or spleen, (d) of two or three adjacent vasa recta of the gut, in gangrene of the gut, and so for the artery to the appendix.

Sinusoids. In parts of certain organs (e.g., liver, spleen, bone marrow, adrenal

glands) the place of capillaries is taken by irregularly wide, tortuous vessels, called *sinusoids*. The lining cells differ somewhat from endothelial cells, many of them being phagocytic, that is to say, capable of engulfing particulate matter, and they are supported by reticular fibres—not by areolar tissue.

Cavernous Tissue. In the corpora cavernosa and corpus spongiosum of the penis and clitoris there are innumerable venous spaces lined with endothelium and separated by fibrous septa containing smooth muscle. This tissue is erectile. In the nasal cavities, especially over the middle and inferior conchae, arterioles open into wide and abundant venous spaces and from these venules arise. This also is erectile. When one has a "cold in the head", the venous spaces dilate and may obstruct the air way. In the placenta the maternal arterioles empty into spaces lined, imperfectly towards the end of pregnancy, with a syncytium. From these the maternal venules lead away, and into them the foetal chorionic villi dangle.

Vascularity. *Cellular tissues* are vascular, e.g., muscles being the cellular engines of the body require much fuel; glands (kidney, thyroid, adrenal, and liver) are very vascular; so, obviously, are the lungs. *Connective tissues* are only slightly vascular: thus, areolar tissue and the fibrous tissues (e.g., deep fascia, tendons, ligaments) have a very meagre blood supply; adipose tissue and bone have a fair supply; but hyaline cartilage, the cornea, and the epidermis are nonvascular. *Nervous tissue.* The grey matter of the brain and spinal cord, being cellular, is more vascular than the white matter and the peripheral nerves.

Distinctive Types of Blood Supply are possessed by the heart, liver, spleen, kidney, and skin—the myocardial circulation (p. 543), the portal (p. 53), the splenic (p. 54), the renal (p. 61–62), and the cutaneous (p. 72).

The Lymphatic System

Tissue fluid is the fluid which bathes the cells (and fibres) of the tissues of the body, and it resembles blood plasma in chemical composition. From this fluid the cells get their nutritive material; to it they give their waste products; and through it they respire. Between the tissue fluid and the plasma of the circulatory blood a constant interchange of fluid and dissolved substances takes place through the semipermeable walls of the capillaries, and by this means the tissue fluid is refreshed.

Most of the constituents of the blood plasma that transude through the walls of the capillaries into the tissue spaces, for the nourishment of the tissues, after undergoing metabolic change, transude back again and return to the heart via the veins. Some, however, transudes into the *lymph capillaries* whence it is drained by *lymph vessels* through *lymph glands* to the great veins at the root of the neck where it rejoins the blood stream. The fluid in the lymphatics is clear and colourless and is called *lymph* (L. lympha = pure, clear water); lymphocytes are added to it as it passes through the lymph glands, otherwise it is free from blood cells.

LYMPH CAPILLARIES occur only where there are blood capillaries, and like blood capillaries they form a closed network, but with a larger mesh. They are especially numerous in the skin and in mucous membranes. In two regions hollow finger-like cul-de-sacs project from the networks: (1) the papillae of the skin, and (2) the villi of the intestines.

THE LYMPH VESSELS draining the networks are colourless, $\frac{1}{2}$ to 1 mm. in diam-

eter, and beaded due to numerous valves. They run in (fatty) areolar tissue. Though more plentiful than veins, they tend to accompany veins and to drain corresponding territories. With the exception of a few lymph vessels at the root of the neck, all lymph vessels traverse one or more lymph glands.

LYMPH GLANDS OR NODES vary *in size* from a pin's head to an olive, and are somewhat flattened. *In colour*, they are pink in life and brownish in the embalmed cadaver; but those draining the lungs are black from inhaled carbon, and after a meal those draining the intestines are white from emulsified fat. *In structure*, they have a fibro-elastic capsule from which trabeculae spread inwards, and the spaces between the trabeculae contain a supporting reticular spongework with reticulo-endothelial cells. The periphery or cortex of the gland is filled with rounded *nodules* of lymphocytes surrounding which are channels, *lymph sinuses*, bridged by reticular fibres and reticulo-endothelial cells. In the centre or medulla of the gland lymphocytes are loosely packed. Lymph is brought to the sinuses of the cortex by several vessels and, after percolating almost stagnantly through them, leaves by vessels arising in the medulla. The glands act as filters for lymph and factories for lymphocytes.

Note. Just as the renal blood passes through two sets of (arterial) capillaries and the portal blood through two sets of (venous) capillaries, so lymph passes through two sets of (lymph) capillaries: (a) in the tissues, and (b) in the sinuses of the glands or series of glands.

The flow of lymph in an immobile limb is almost negligible, but during muscular activity it is very active. Lymph flows in the same direction as venous blood, that is, towards the heart, due probably to (1) rhythmical contraction of the vessels, (2) intermittent pressure (e.g., muscular action) on the valved vessels, (3) negative pressure or suction within the thorax, and (4) positive pressure within the abdomen during inspiration. Hence, when massaging a part, the stroking should be towards the heart.

We all know that when small blood vessels and capillaries are cut, the blood soon clots, bleeding is arrested, and the cut is sealed. A broken lymph capillary, however, may remain open for days, permitting the entry of debris, fluid, and poisons if they are present. (Clark and Clark.)

MAIN CHANNELS. Three paired lymph trunks (1) the *jugular* accompanying the internal jugular vein in the neck, (2) the *subclavian* accompanying the subclavian vein in the upper limb, and (3) the *mediastinal* from the thoracic viscera, end either separately or together near the angle of confluence of the internal jugular and subclavian veins. A fourth channel, the *thoracic duct*, drains the territory below the diaphragm (the liver in part excepted); it is described on p. 568 and depicted in fig. 607.

INVESTIGATION. By forcing valves, main lymph trunks may be injected in retrograde direction, but not the smaller ones. These and the lymph glands into which they drain can be rendered conspicuous from the network end. This is done by plunging a hypodermic needle at random into an areolar plane (e.g., subcutaneous, submucous, subserous, fascial) and injecting Prussian blue (or some other pigment that is insoluble in water and tissue fluids) dissolved in ether and turpentine. As the solvents evaporate the pigment is deposited within the lymphatics, which can be dissected. Naturally, the point of the needle will

not in all instances enter a lymphatic, if such is present, at the first attempt.

If, while thus injecting, say the subserous network of the stomach, you deliberately obstruct the efferent vessel in which the coloured fluid is visible flowing towards a lymph-gland, it will be observed to find egress by one of several neighbouring vessels. From this you will appreciate that the normal anatomical outflow may be greatly diverted in pathological (e.g., cancerous) conditions associated with obstruction.

EXCEPTIONS. Lymph capillaries are not present in epithelium (e.g., epidermis), cartilage or other tissues devoid of blood vessels; neither are they present in parts possessing sinusoids, nor in the brain or eyeball—though in the brain the perivascular spaces, continuous with the subarachnoid space, substitute for them. Lymph capillaries do not accompany the blood capillaries between the alveoli of the lungs, nor in the glomeruli of the kidneys, since these capillaries are not nutritive in function—but in the lungs lymph vessels do accompany the bronchial vessels.

LYMPHOID TISSUE such as occurs in lymph glands, the palatine, lingual and pharyngeal tonsils, the solitary and aggregated follicles of the intestine, the appendix, the thymus gland and the corpuscles of the spleen are best developed in youth, and diseases of this tissue are commonest in youth.

The Foetal Circulation

Nucleated red cells are the only red cells in the foetal blood until the second foetal month; they are numerous until the end of the seventh month and they may be present until a few days after birth. But these cells cannot be recovered from the maternal blood, because the two circulations—foetal and maternal—are separate and closed. Through the foetal villi nutritive material and oxygen permeate from mother to foetus; waste products and carbon dioxide permeate from foetus to mother. The functions of the placenta, therefore, are concerned with nutrition, excretion, and respiration. In the foetus the pulmonary, portal, and renal circulations are of little account; the placental circulation is paramount.

Blood, charged with nutritive material and oxygen, leaves the placenta in the *umbilical vein.* This vein traverses the umbilical cord outside the foetus and the free edge of the falciform ligament of the liver inside, and it ends in the left portal vein. Some of the blood, thus brought to the left portal vein, then flows through the liver, leaves it by the hepatic veins, and enters the inferior vena cava; the remainder is short-circuited by the *ductus venosus.* This vessel, which occupies a sulcus behind the liver, connects the left portal vein to the inferior vena cava just below the diaphragm. The blood in this terminal part of the i. v. cava has a three-fold source: from (1) the lower limbs and abdominal wall, (2) the gastro-intestinal tract (via portal vein), and (3) the placenta (via umbilical vein). Hence, the purest blood to reach the foetal heart travels through the terminal part of the i.v. cava to the right atrium.

The Traditional View. In the foetus, it is held that the blood from the i. v. cava is directed by a large endocardial fold, the *valve of the i. v. cava,* across the right atrium and through an opening in the interatrial septum, the *foramen ovale,* into the left atrium, thereby short-circuiting the pulmonary circuit. Thence it passes through the left ventricle into the ascending aorta and aortic arch, and by their branches it is distributed to the heart, head and neck, and upper limbs,

which therefore receive "pure" blood. It is blood that has been purified in the placenta and returned by the umbilical vein and ductus venosus to the i. v. cava and so to the right atrium (*fig. 39*).

The blood from the heart, head and neck, and upper limbs returns via the superior vena cava (and coronary sinus)

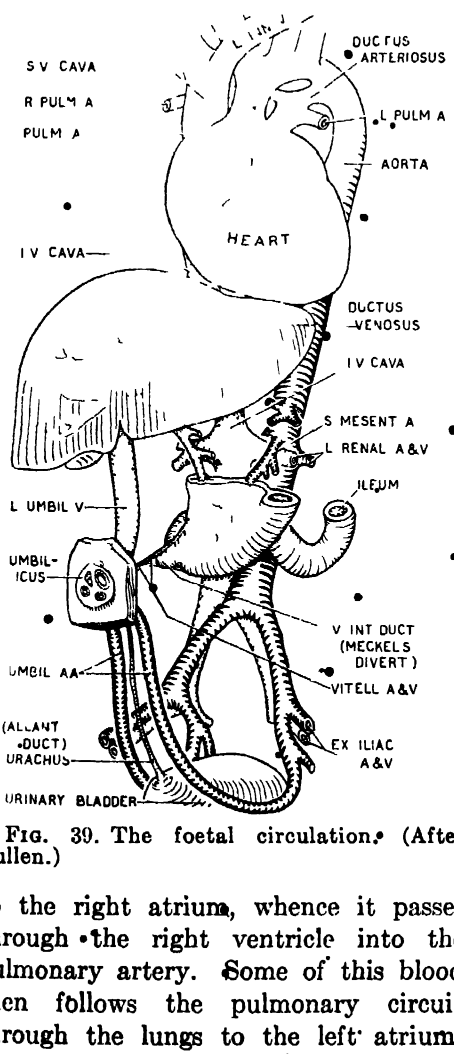


FIG. 39. The foetal circulation. (After Cullen.)

to the right atrium, whence it passes through the right ventricle into the pulmonary artery. Some of this blood then follows the pulmonary circuit through the lungs to the left atrium; but most of it is short-circuited to the aorta by a vessel, the *ductus arteriosus*, which connects the left pulmonary artery to the aortic arch just beyond the origin of the left subclavian artery. Beyond this connection the united streams descend through the aorta and common iliac arteries; some to be distributed to the abdomen and lower limbs, some to the placenta. The umbilical or placental arteries, one on each side, pass by the sides of the bladder and up the anterior abdominal wall to the umbilicus, thence along the umbilical cord to the placenta where waste products and carbon dioxide are discharged.

From this account it would appear (a) that the kidney has no short-circuit, (b) that the liver has one (ductus venosus), and (c) that the lungs have two (foramen ovale and ductus arteriosus), and, furthermore, that the heart, head, neck, and upper limbs receive the purest blood.

Changes at Birth. LUNGS. The child cries; the lungs begin to expand (p. 532) and assume their functions, whereupon the foramen ovale and the ductus arteriosus close—the former to be represented by the *fossa ovalis*, the latter by a fibrous cord, the *ligamentum arteriosum*.

PLACENTA. The cord is tied about 2 inches from the umbilicus, cut, and discarded with the placenta; so, the right and left umbilical (hypogastric) arteries become thrombosed and fibrous (*obliterated umbilical arteries*) beyond the points at which the last branches within the body (superior vesical arteries) are given off; and the umbilical vein does likewise and becomes the *round ligament* of the liver. There is, therefore, less blood entering the i. v. cava to be directed at the foramen ovale.

LIVER. The ductus venosus also becomes a fibrous thread, the *ligamentum venosum;* so, all the blood in the portal vein must now pass through the liver.

The Modern View. Highly original and ingenious experiments by Pohlman and careful calculations by Patten have

thrown doubt on certain aspects of this traditional view of Sabatier, for example, that the caval blood streams do not mix and that the short circuits close suddenly.

The Recent View. Barclay, Barcroft, Barron, and Franklin, after injecting radio-opaque substances into veins of living foetal sheep and taking moving X-ray pictures, observed that (1) the whole of the superior caval blood passes through the right atrium, right ventricle, and pulmonary trunk, and thence (a) via the right and left pulmonary arteries to the lungs and (b) via the ductus arterio-

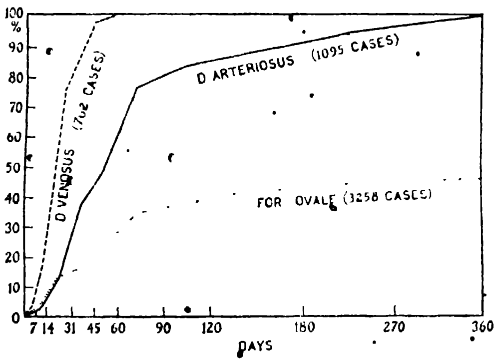


FIG. 40. Dates of permanent closure of the ductus venosus, ductus arteriosus and foramen ovale during the first year of life. (After Scammon and Norris.)

sus into the descending aorta; also that (2) the main part of the inferior caval blood passes through the foramen ovale into the left atrium, and that the minor part passes with the superior caval blood into the right ventricle; and that (3) the ductus arteriosus, which may be regarded as a long muscular sphincter, closes functionally a few minutes after delivery, and (4) subsequent injections, made at five minute intervals for nearly two hours after delivery, show that the ductus remains closed (though perhaps opening intermittently) and (5) that the functional closure of the foramen ovale, which tends to precede that of the ductus, is apparently dependent on the onset of respiration. These findings, then, substantiate the traditional view.

Physiological occlusion is not to be confused with anatomical obliteration.

From the accompanying chart (*fig. 40*) it is seen that the times of complete obliteration of the orifices are highly variable. The foramen ovale, though closed functionally, remains unobliterated (i.e., admits a probe) in about 25% of adults.

THE PERIPHERAL NERVES

Man is not the largest of the animals, nor are his vision, his hearing or his sense of smell the most acute; he is not the strongest of the animals, the most fleet of foot nor even the longest-lived; but he is superlative in the quality of his central nervous system and he possesses a hand which does its bidding.

The central nervous system requires preferential treatment not given in this book, but the peripheral and autonomic nervous systems are described here. Their place is shown in the following table:

Subdivisions of the Nervous System

Central Nervous System	Brain Spinal cord

Peripheral Nervous System	Cerebro-spinal nerves
	  Cranial nerves—12 pairs
	  Spinal nerves—31 pairs
	Autonomic nervous system
	  Sympathetic
	  Parasympathetic

The central n. system, also called the somatic n. system (L. soma = the body), controls the voluntary muscles of the body and is concerned with things both above and below the level of consciousness. The autonomic nervous system,

also called the involuntary, vegetative or visceral nervous system, controls the involuntary muscles, the viscera, and parts over which we do not exercise voluntary control and of which, for the most part, we are unconscious (e.g., action of the heart, movements of the viscera, secretion of bile).

In the peripheral nerves (e.g., facial, median, digital) encountered in dissection, autonomic fibres are mingled

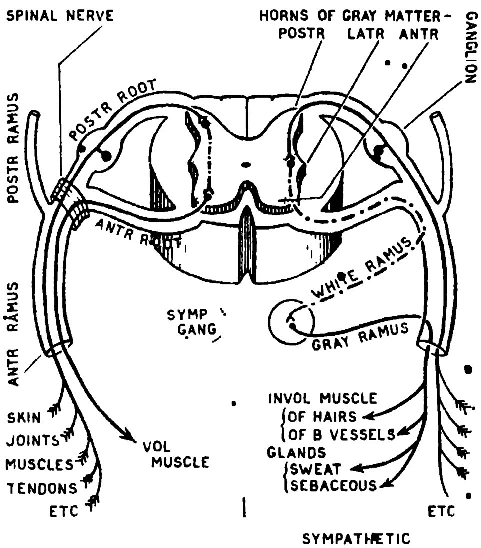


FIG. 11. The composition of a peripheral nerve.

with cerebro-spinal fibres (*fig. 11*). Like telephone wires, nerves transmit messages with incredible speed to the parts with which they are connected. Certain chemicals, *hormones*, secreted by glands enter the bloodstream and carry messages to distant parts, but this blood-borne transmission is relatively slow.

Peripheral nerves lie in fatty-areolar tissue, usually accompanied by an artery and a vein. Main branches course between muscles; cutaneous branches run in the superficial fascia close to the deep fascia.

Structure. Nerves are made up of nerve bundles, which in turn are made up of nerve fibres. A loose sheath of areolar tissue (epineurium), continuous with the surrounding areolar tissue, encases the entire nerve and unites the individual bundles. Each bundle has a thicker sheath, the *perineurium*, which branches when the bundle branches and which accompanies every fibre to its destination. Between the fibres are some delicate areolar septa (endoneurium).

A nerve fibre consists of a central thread, the *axis cylinder*, encased in a thick, soft, white tube, the *myelin sheath*, around which there is a thin, but tough, tubular membrane, the *neurilemma*. A nerve fibre may be likened to a pencil, the axis cylinder being the lead, the myelin sheath the wooden shaft, and the neurilemma the enamel coating. The axis cylinder is the essential part of the fibre. It is continuous throughout the length of the fibre and at the periphery it separates into many *fibrils*. The myelin (medullary) sheath is composed of fatty material and is interrupted at short intervals (1 mm. or less) called *nodes of Ranvier*. It is the myelin sheath that gives whiteness to nerves and to nerve tracts in the spinal cord and brain; in its absence nerve tissue looks gray.

The neurilemma (nucleated sheath, primitive sheath of Schwann) has a nucleus embedded in protoplasm between each node. If a fibre is pinched, the axis cylinder and the myelinated sheath will rupture, but the neurilemma may remain intact. Since regeneration of a severed or ruptured nerve depends upon the presence of a neurilemma, there can be no regeneration in the central nervous system (i.e., brain and spinal cord) and optic nerve, because in them this sheath is wanting.

Nerve fibres are processes of nerve cells. A peripheral nerve fibre is the process of a cell whose body is situated in the brain, spinal cord or related ganglia. Turn, then, to the spinal cord (spinal medulla).

The Spinal Cord lies within the vertebral canal. The vertebral canal (or a vertebral foramen), being too small to admit a finger, the cord is of smaller diameter than a finger, but in length (18″) it equals the femur or the vas deferens The cord is surrounded by 3 membranes: (1) the *pia mater* which, like a delicate skin, clings tenderly to the cord, (2) the *arachnoid mater* (Gk. = like a cobweb) which is joined to the pia by threads and is flimsy, and (3) the *dura mater* which is tough and fibrous, but is easily split longitudinally, owing to the direction of its fibres. The arachnoid mater is separated from the pia by a space, the *subarachnoid space,* filled with cerebrospinal fluid (C.Sp.F.). This fluid presses the arachnoid against the dura thereby obliterating a potential space, the *subdural space.*

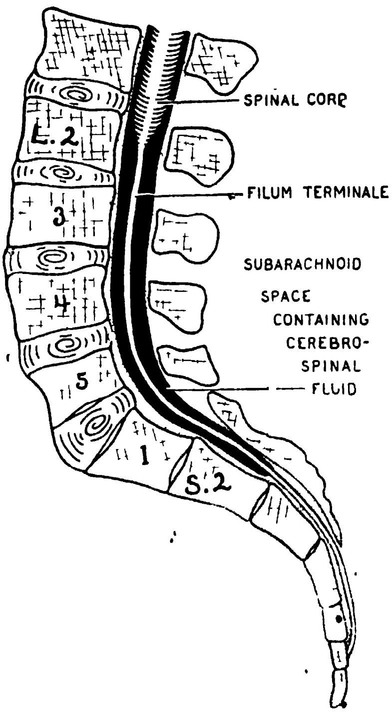


FIG. 12. The spinal cord ends at lumbar vertebra 1–2, the subarachnoid space at sacral vertebra 2

In the embryo the spinal cord extends down to the coccyx, but as development proceeds, owing to the greater growth of the vertebral column, it is drawn upwards, so that at birth it extends only to vertebra L. 3, and in the adult to the upper part of L.2 (*fig. 12*). Flexing the column draws the cord temporarily higher. A strong, glistening thread, the *filum terminale*, largely composed of pia mater, attaches the end of the cord to the back of the coccyx even in the adult

A broad band of pia, the *lig. denticulatum*, projects like a long lateral fin from each side of the cord and lies between the ventral and dorsal nerve roots From the free margin of this ligament strong toothlike processes, one for each segment, pass to the dura and tack down the arachnoid. The highest tooth or dens of each ligament is at the level of the foramen magnum, the lowest tooth varies in level from T 12 to L. 2 (I. B. Macdonald). Hence, the spinal cord within its waterbath is fixed cranially to the brain; caudally via filum terminale to the coccyx, and laterally via ligg denticulata to the dura

The *spinal dura* is free within the vertebral canal. It is however, adherent to the margin of the foramen magnum and is there continuous with the cranial dura. It is fixed caudally to the coccyx by the filum terminale which, as it passes beyond the closed end of the dural sac, acquires an adherent dural covering. The ventral and dorsal nerve roots likewise acquire adherent dural coverings—as a result the

nerves are twice as thick outside the dura as inside.

The sensory *nerve supply* to the dura is from the meningeal twigs of the spinal nerves.

On *flexing the spinal column*, the spinous processes spread apart, the vertebral canal lengthens (up to 7 cm.), and the dural sac stretches. In the cadaver, full flexion of the column exerts traction on the dural sac so that nerves L. 1 and 2 are drawn from 2 to 5 mm. within the intervertebral foramina. L.3 is withdrawn less, and L. 4 negligibly. On the other hand, "*straight-leg raising*" through 15° to 30° exerts traction on the sciatic nerve; through 60° to 80° it pulls L. 5, S. 1, and S. 2 downwards through 2 to 5 mm., but the effect on L. 4 is negligible. Inman and Saunders.)

In the adult the subarachnoid and subdural spaces extend to the body of sacral vertebra 2. So, between L. 2 and S. 2 there is no cord, but instead there is the filum terminale; and the roots of the lower spinal nerves, which have been drawn upwards with the cord, loosely fill the space. They are enclosed in the sac of cerebro-spinal fluid, here somewhat dilated, and resemble a horse's tail, *cauda equina*. A hollow needle entering the subarachnoid space to draw off C. Sp.. F. above L. 2 may permanently damage the spinal cord; entering lower down it would merely push the nerves of the cauda equina apart.

The cord, so protected in its cushion of fluid and so anchored, is seen on cross-section to have an H-shaped field of gray matter enveloped in a zone of white matter. The anterior and posterior limbs of the H, called the *anterior* and *posterior horns* or *gray columns*, divide the white matter of each side into *anterior, lateral,* and *posterior white columns*. A groove in front, the *antero-median fissure*, and a septum behind, the *postero-median septum*, separate the right and left sides of white matter. A canal, the *central canal of the cord*, which is obliterated in postnatal life, runs through the gray matter.

Two continuous longitudinal rows of delicate *nerve fila* (L. filum = a thread), made up of nerve fibres, are attached to each side of the cord along the lines of the apices of the anterior and posterior columns of gray matter. The fila of the anterior row converge laterally in groups of a dozen or so to form *anterior nerve roots*, and the fila of the posterior row do likewise to form *posterior nerve roots*. The respective anterior and posterior roots pierce the dura about 2 mm. apart, one in front of the other—or rather they carry it before them, as do the cranial nerves. They then continue laterally to the intervertebral foramina where each posterior root is swollen because it contains the cell bodies which make up a *posterior root ganglion*. Just beyond this, the two roots unite and their fibres mingle to form a *nerve trunk*. This, after a few mm., divides into a large *anterior* and a small *posterior ramus*. The section of the cord from which the fila contributing to a root spring is called a *segment*. Since there are 31 pairs of spinal nerves, the cord is said to have 31 segments. But segmentation of the cord is incidental—not fundamental—and in cases where one side of a vertebra fails to develop the corresponding fila group themselves with fila of the neighbouring roots.

A Nerve Unit or *neuron* has 3 parts: (1) the cell body or *cyton*, (2) a process or *dendron* (or processes) which transmits impulses to the cyton, and (3) a process or *axon* which transmits impulses from the cyton. An entire neuron may be microscopic in size; on the other hand, a process may be several feet long (e.g., a fibre of the sciatic nerve).

A posterior nerve root transmits impulses to the cord; it is *afferent* or sensory. An anterior nerve root transmits impulses from the cord; it is *efferent* or motor, causing muscles to contract. The cell bodies of the posterior root fibres lie in the posterior root ganglia. The dendrons conduct afferent impulses from endings in the skin, joints, muscles &c. to the cytons in the posterior root ganglia; thence via the fila of the posterior root to the cord. Within the cord the fibres branch; some branches ascend in the cord, others descend, still others at once turn into the gray matter of the posterior horn where they synapse (i.e., make contact) with the dendrons of short *connector* (*intercalated*) *cells* whose axons in turn synapse with the dendrons of large multipolar cells in the anterior horn. The axons of these motor cells emerge in the anterior root fila and end in motor end-plates of voluntary muscles.

These neurons—afferent, connector, and efferent—constitute a simple spinal *reflex arc*. On its integrity depends *muscle tone*. The arc functions thus: if one's finger is touched, even during sleep, one moves it; if it is pricked or burnt one withdraws the limb. In the one case a simple reflex arc is invoked; in the other, afferent impulses spread more widely, even to the opposite side of the body, perhaps arousing consciousness, due to the ascending and descending and crossing fibres by which impulses spread to other parts of the cord and to the brain.

The area of distribution of a severed artery can, if the anastomosis is ample, be taken over by other arteries. Not so with nerves; just as cutting a telephone wire isolates a house, so cutting a motor nerve isolates the muscle fibres supplied by it, and they die. Regeneration, with restoration of function, however, may take place.

Nerve Plexuses. Anterior nerve rami and the branches of anterior nerve rami communicate with adjacent rami and branches to form plexuses, thereby widening the influence of the individual segments of the spinal cord. Close to the vertebral column the anterior rami of nerves C. 1-4 form the cervical plexus, those of C. 5-Th.1 the brachial plexus, L.1-4 the lumbar plexus, L.4—S.4 the sacral plexus, and S.4-Co.1. the coccygeal plexus.

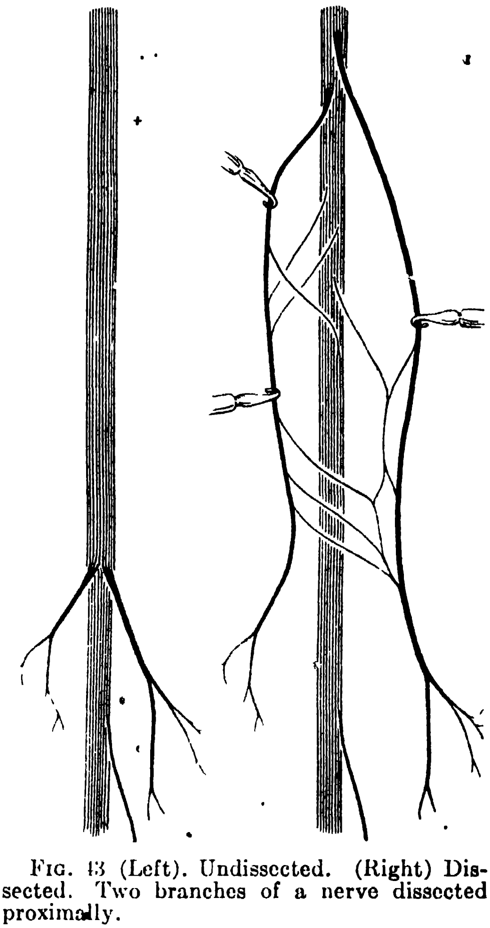


FIG. 43 (Left). Undissected. (Right) Dissected. Two branches of a nerve dissected proximally.

Nerves anastomose more peripherally

also, e.g., the musculocutaneous and median usually communicate in the arm; the median and ulnar communicate in the upper part of the forearm, superficially in the palm, and again deep in the palm under cover of the thenar muscles. Cutaneous nerves communicate freely with adjacent nerves and overlap them with the result that severing a cutaneous nerve diminishes sensation in its territory without as a rule abolishing it. Peripheral nerves are themselves plexuses: their fibres do not run parallel courses but are plaited, not unlike the tendon fibres in figure 31-A. The branch of a nerve is usually bound to the parent stem for between $\frac{1}{2}''$ and $2\frac{1}{2}''$ by areolar tissue, and the level at which it leaves the parent stem varies within this range. Proximal to this, the strands of the branch take part in the plait, and attempts to free the branch more proximally lead to its destruction (*fig. 43*).

Axiom. If the individual motor nerves, supplying a group of muscles developed from a common muscle mass, are traced proximally up the parent stem, they will be found to form a single bundle. This bundle can be traced but a short distance before its fibres separate and become plaited with the fibres of the parent stem (e.g., the nerves to the Gastrocnemius, Soleus and Plantaris spring from a common bundle, but the nerve to the Popliteus does not spring from this bundle, for the reason that the Popliteus is not related to these 3 muscles morphologically, although it chances to be closely related to them topographically).

Blood Supply. The peripheral nerves are supplied by a succession of anastomosing nutrient vessels, *arteriae nervorum*, derived from the nearest arteries which are seldom more than $\frac{1}{4}''$ to $\frac{1}{2}''$ away. In number, size, and origin they are inconstant. Thus, occasionally the median nerve may receive no artery between axilla and elbow, the circulation being maintained by a large intraneural descending vessel which enters it at the axilla; but, when the supply vessels are small, they are necessarily numerous. On reaching a nerve the artery usually divides into ascending and descending branches which by anastomosing from longitudinal chains near the surface of the nerve (epineural) and between the nerve bundles (interfascicular). From these, finer branches pass into the nerve bundles (intrafascicular) where they form a more or less oblong network that runs throughout the length of the nerve.

The veins, *venae nervorum*, have an intraneural pattern similar to that of the arteries. Some of the veins from the cutaneous nerves end in the cutaneous veins, but most of them pierce the deep fascia and end in muscle veins. The veins of the deep nerves end either in muscle veins or in the venous plexus around an artery. (Sunderland.)

Distribution. In describing the distribution of a peripheral nerve (a) the muscles, (b) cutaneous areas, (c) articulations, and (d) blood vessels it supplies should be given, and (e) common variations remembered. Muscular branches are remarkably constant; cutaneous branches are variable, and about the hand and foot the variations are of considerable clinical importance (*fig. 95*).

CHAPTER 2

THE DIGESTIVE SYSTEM

Animals, like plants, absorb their food in fluid form. In order that solid food shall become fluid, preparatory to being taken into the blood stream, it must undergo certain mechanical and chemical changes. The parts of the body set aside for this purpose are known as the digestive or alimentary system. This is essentially (1) a long hollow tube, the alimentary canal, through which food is propelled, and (2) certain accessory glands (*fig. 44*).

The *alimentary canal* begins at the lips, traverses the neck, thorax, abdomen and pelvis, and ends at the anus. Its successive parts are: the mouth, pharynx, oesophagus, stomach, small intestine (subdivided into duodenum, jejunum, and ileum) and large intestine (subdivided into appendix, caecum, colon, rectum, and anal canal). The *accessory glands* are: the salivary glands (parotid, submandibular, and sublingual), the liver and pancreas. Associated with these is the spleen.

The Mouth. To survive, animals must eat. And, in search for food, they advance, mouth-end foremost. Around the mouth the organs of special sense are developed: the eyes to locate food by *sight*, the nose by *smell*, and the lips and tongue by *touch*. When the food is in the mouth, the *taste buds* decide if it is good, in which case it is swallowed; if not, it is rejected. The ears advise if there is *sound* of danger, when safety may be sought in flight. Hence, the brain establishes itself at the mouth end of the body.

The mouth or buccal cavity is bounded externally by the lips and cheeks. The cleft between the upper and lower lips is the *aperture* of the mouth or oral fissure. The *teeth* are arranged in the form of an upper and a lower dental arcade, 16 in each arcade, and are set in the upper jaw or maxillae and lower jaw or mandible. The horseshoe-shaped space between the lips and cheeks externally and the teeth and gums internally is the *vestibule* of the mouth. The space bounded externally by the teeth and gums is the *mouth proper*. From the floor of the mouth rises the *tongue*; the roof comprises the *hard* and *soft palates* and the median finger-like process, the *uvula* in which the soft palate ends.

From near the posterior free border of the soft palate two folds descend on each side. The anterior fold, the *palato-glossal arch*, descends to the side of the tongue at the junction of its anterior $\frac{2}{3}$ and posterior $\frac{1}{3}$. The posterior fold, the *palato-pharyngeal arch*, descends on the side wall of the pharynx. The triangular space between the two arches and the side of the tongue is occupied by the palatine *tonsil*. (*Fig. 725.*)

The mouth is limited posteriorly by the posterior free border of the soft palate, the palato-glossal arches, and a V-shaped groove, the *sulcus terminalis*, that crosses the dorsum of the tongue between the right and left palato-glossal arches. The tonsils and the posterior third of the tongue are, therefore, situated behind the mouth in the oral part of the pharynx.

MASTICATION. It is the duty of the incisor teeth (L. incidere = to cut) to bite

off pieces of food, and of the molar teeth (L. mola = a millstone) to grind them. One duty of the tongue is to supply the molars with food from the mouth proper; such food as falls into the vestibule is

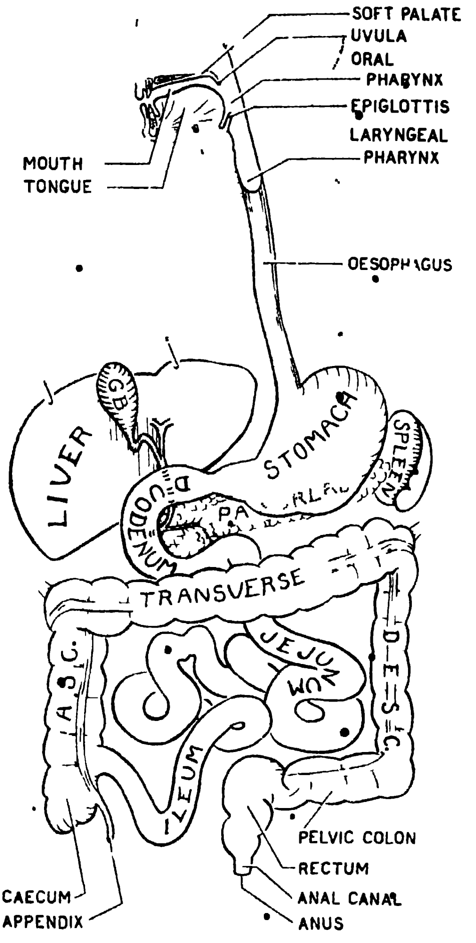


FIG. 44. Diagram of the digestive system.

returned to the molars by the lips and cheeks. The food is commonly coarse; so, the mouth requires a protective lining. It is lined with stratified squamous epithelium, resembling epidermis but lacking a stratum granulosum and stratum lucidum; and the surface cells, though flattened, retain their nuclei and do not cornify. The epithelium is lubricated and kept moist by the mucous and serous secretions of small, "pin head", racemose glands that cover the palate, lips and cheeks These glands do for this epithelium what sebaceous and sweat glands do for the epidermis; they are aided by the secretions of the 3 paired *salivary glands* (parotid, submandibular, sublingual).

THE PAROTID GLAND (Gk. para = beside; ous (otos) = the ear) lies below the ear in the space between the ramus of the jaw and the mastoid process; its duct opens into the vestibule of the mouth beside the 2nd upper molar tooth. The SUBMANDIBULAR (SUBMAXILLARY) GLAND lies under shelter of the body of the mandible; its duct opens on to a papilla beside its fellow, behind the lower incisor teeth On opening your mouth and raising the tip of the tongue, water secretion may be seen welling up from the orifices Each SUBLINGUAL GLAND produces a ridge on the side of the floor of the mouth beneath the tongue; it has many fine ducts which open on to the ridge. (*Figs. 622, 734*)

The salivary glands have a mucous secretion or a serous secretion or both; the serous secretion (ptyalin) digests free starch, but cannot break down cellulose. The saliva moistens the food which has been ground into small particles by the teeth. This the tongue rolls into a bolus or lubricated mass easily swallowed—dry food is swallowed with difficulty. Saliva keeps the lips and mouth pliable in speaking. It also aids in the healing of wounds (e.g., a bitten tongue or the empty socket of an extracted tooth heals readily). The amount secreted is about 1 litre daily.

THE NERVES of general sensation for the roof of the mouth and upper teeth

are derived from the maxillary nerve, and for the floor of the mouth, anterior ⅔ of the tongue and lower teeth from the mandibular nerve. The facial nerve (via the pars intermedia) carries secretory fibres to the submandibular and sublingual glands and assists the glosso-pharyngeal nerve to supply the parotid gland.

SUCKING. Place a finger in your mouth and, while sucking it, note that your lips grasp it, that a groove forms along the middle of the tongue, and that the tongue recedes from the palate, thereby creating a vacuum. Note also that, while sucking fluid through a straw, you can breathe in and out through the nose. This is possible, since the Palato-glossi shut the mouth off from the pharynx. A child with a cleft palate cannot suck effectively, because air, drawn in through the cleft, prevents the formation of a vacuum within the mouth.

SWALLOWING. While food is in the mouth, it is under voluntary control, but when it enters the pharynx this control is lost and it is propelled onwards through the oesophagus to the stomach, where digestion begins. During the act of swallowing, the pharyngeal wall contracts on the soft palate which rises to meet it, thereby shutting off the naso-pharynx (region above the soft palate). Hence, breathing is suspended temporarily and food cannot be forced into the naso-pharynx.

The Pharynx and Oesophagus are merely passages and, like the mouth, are protected by stratified squamous epithelium. The muscle coat of the pharynx and upper half of the oesophagus, though voluntary in structure, is not under voluntary control; in the lower half of the oesophagus (and onwards to the anus) it is involuntary or smooth. In the pharynx the muscle coat has 3 overlapping layers, the *constrictors* (*fig. 669*). In the oesophagus (and onwards to the anus) the muscle coat has 2 layers: an inner circular and an outer longitudinal. Throughout the oesophagus (and onwards to the anus) the muscle coat is separated from the epithelial lining by a thick tunic of areolar tissue. This is split into an inner and an outer part by a thin layer of smooth muscle, the *lamina muscularis mucosae*: (a) the inner part, called the *lamina propria*, with the epithelial lining and the lamina muscularis mucosae constitute the *mucous membrane* or *mucosa*; (b) the outer part is called the *submucous coat* or *submucosa*. The oesophagus and duodenum are peculiar in possessing branching (racemose) glands in their submucous coats.

The Stomach lies in the abdomen and, being a receptacle for food and requiring to expand, to contract and to move about, it possesses a serous (peritoneal) coat, such as the relatively inexpansible pharynx and oesophagus do not require. It thus possesses the same 3 coats as the oesophagus (mucous submucous muscular) plus a serous coat—as do the intestines also. The lining epithelium is a single layer of clear, columnar cells which (though not goblet cells) secrete a protective mucus. About 3,000,000 test-tube-like glands, with ends bent (L-shaped), pervade the lamina propria and open at the apices of conical evaginations of the mucous coat. The peripheral, *parietal*, cells of the glands secrete hydrochloric acid which is necessary to the action of the pepsin secreted by the remaining, *central*, cells. Pepsin initiates the digestion of proteins. The outlet of the stomach, the *pylorus* (Gk. = a gatekeeper) is guarded by a strong sphincter of circular fibres. Absorption is not a notable

feature of the stomach, though alcohol, sugar and water are to some extent absorbed. (*Figs. 216, 259.*)

The Intestine or gut is divisible into two parts: (1) the small intestine, about 20 feet long, and (2) the large intestine, about 6 feet long.

STRUCTURE. The intestine has four coats (a) serous and subserous, (b) muscular, (c) submucous and (d) mucous. The *serous* or *peritoneal coat* overlies a fine, subserous layer in which fat may appear, as in the appendices epiploicae of the large gut. The *muscle coat* consists of two tubes, an outer thin longitudinal and an inner thick circular, separated from each other by enough areolar tissue to allow each tube some independent movement. The longitudinal muscle forms a complete coat for the small gut and for the extreme ends of the large gut (appendix and anal canal), but in the caecum and colon it is disposed in three equally spaced bands or taeniae, each about ⅓″ wide, and it clothes the rectum completely in front and behind, but meagrely at the sides. The circular muscle is complete throughout the small and large guts. As at the outlet of the stomach (pylorus) so at the outlet of the intestine (anal canal) the circular muscle is thickened to form an involuntary sphincter, the sphincter ani internus. The *submucous coat* is areolar and strong. In it the main vessels and nerves run; on it—not on the muscle coats—the strength of the gut depends; in fact, it is from this coat that catgut (violin strings and surgical sutures) is made. The *mucous coat* throughout the entire gut is lined with a single layer of columnar cells whose borders are longitudinally striated, and between these are numerous goblet cells. In the outer part of the mucous coat there is a thin layer or tube of smooth muscle, the *lamina muscularis mucosae*. This extends throughout the gut, applied to the submucous coat. Between the epithelium internally and the muscularis mucosae externally there is a thick layer of special connective tissue, the *lamina propria*, in which lymphocytes are diffused. Straight test-tube-like evaginations of the epithelial surface, the *intestinal glands* (crypts of Lieberkuhn), project outwards into the propria; these are closely packed together and are lined chiefly by *columnar* and *goblet cells*. Finger-like processes of the propria, the *villi*, 0.5 to 1.5 mm. long and covered with columnar and goblet cells, project freely into the lumen of the gut. These villi extend throughout the small gut, from pylorus to ileo-colic valve, but in the foetus they are present in the large gut also. Running down the middle of each villus there is a lymph vessel, a *lacteal*; at one end it is blind; at the other it opens into the lymph plexus of the mucosa. Wisps of muscle, derived from the muscularis mucosae, ensheath the lacteal, and around the sheath is a plexus of blood capillaries.

FUNCTIONS. The structure of the mucous membrane of the gut is related to its functions. Thus, the partially digested food leaving the stomach is mixed with hydrochloric acid and pepsin, is fluid, and is relatively free from bacteria. In the upper part of the small gut (3″ beyond the pylorus) the ferments of the pancreas and the bile are added to the intestinal ferments. Here digestion continues and absorption of water and digested products begins. These processes are most active in the duodenum and they diminish as the large gut is approached. The essential function of the large gut is to dehydrate the intestinal contents; the bacteria present break down cellulose.

Accordingly, the mucous surface of the small gut is enormously increased by permanent folds of mucous membrane, the *plicae circulares*, which run circularly (actually spirally) for short distances. These begin 1 or 2 inches beyond the pylorus, are closely packed, and about 6 mm. high. Gradually they become fewer and lower, and finally disappear about the lower part of the ileum. (*Fig. 279.*)

As the distance from the entrance of the pancreatic juices and the bile increases (a) the intestinal contents become less fluid and their progress more slow; hence, in the large gut more lubricating mucus being required, goblet cells are more plentiful; and (b) the antiseptic properties of the ferments become weaker; hence, the lymphocytes, which everywhere pervade the lamina propria, also accumulate in *solitary nodules*, 1-2 mm. in diameter; these are plentiful in the ileum and numerous in the colon. Large accumulations of lymphocytes, *aggregated nodules* (*Peyer's patches*), about ½″ wide by 1″ to 2″ long occur within the ileum at the antimesenteric border; some of these burst through the muscularis mucosae and, by enlarging on its submucous aspect, acquire a collar-stud shape.

The *ileo-colic valve* (ileo-caecal valve). In the last few inches of the ileum, the circular muscle, though not thickened, behaves as a sphincter retarding the too rapid emptying of the small gut. The end of the sphincter pouts into the caecum and, when the caecum is distended, has an upper lip which overhangs a lower lip and apparently directs the emitted contents downwards into the caecum. From each of the two commissures of the lips a mucous fold, a *frenulum*, extends transversely round the gut.

The mucous coat of the appendix is practically a continuous series of solitary nodules, hence the *appendix* has been called the "intestinal tonsil". In dissecting room subjects the lumen is commonly partly occluded and so cannot be injected.

Around the *anal canal* there are two sphincters: (1) involuntary, consisting of a thickening of the circular muscle, and (2) voluntary, consisting of skeletal muscle.

NERVE SUPPLY. The intestinal canal is supplied by sympathetic and parasympathetic nerves. These take part in two plexuses (1) the *plexus of Auerbach*, placed between the longitudinal and circular layers of the muscle coat, and (2) the *plexus of Meissner*, placed within the submucous coat. The sympathetic nerves are connected with segments Th. 6 to L.3; the parasympathetic nerves supplying parts cranial to the left colic flexure are derived from the vagus nerves; those to parts caudal to the flexure are derived from the pelvic splanchnic nerves (*fig. 764*). The nerves reach the intestine with the blood vessels. The stomach is supplied in a similar way. The stomach and intestines continue to function even after the nerves are divided.

The Liver

The liver is the largest organ in the body. Attached to its under surface is the *gall bladder*; this extends backwards to a transverse fissure, the *porta hepatis*, through which the *hepatic ducts* conduct bile from the liver and through which the *portal vein* (conducting blood laden with products of digestion) and the *hepatic artery* (conducting oxygenated blood) enter the liver. After the blood has circulated through the liver, it leaves the posterior surface via the hepatic veins to enter the inferior vena cava.

The liver is a gland of compound tubular design. The cells of the tubules elaborate an *exocrine* (*external*) *secretion*, called bile, into the tiny lumina of the tubules. Each tubule, called a *bile capillary* or *canaliculus*, is really a continuous series of minute spaces between two contiguous rows of liver cells. At the periphery of the lobule it drains into a system of ducts, the *bile passages*, which communicate with the gall bladder and with the duodenum (*fig.* 254 and p. 247).

These same liver cells also elaborate an *endocrine* (*internal*) *secretion*. This is possible, since the surfaces of the cells not forming canaliculi are in apposition with blood capillaries. These are not simple capillaries but *sinusoids* (p. 37). Helping to line the sinusoids are phagocytic cells, *Kupffer's cells*, which, like similar cells in the spleen and bone marrow (reticulo-endothelial cells), help to dispose of effete red blood cells. From these they make bile pigment (bilirubin) which they turn over to the liver cells for disposal.

The tubules (cords of cells) and the sinusoids lying between them are arranged in polyhedral prisms, called *lobules*. These are 1–2 mm. in diameter and are somewhat longer than they are wide (*fig.* 45). Through the centre of each lobule runs a vein, the *central vein*. The cords of cells and the sinusoids radiate from the central vein to the periphery of the lobule which, though not conspicuous in man, is clearly outlined in the pig by connective tissue septa.

THE BLOOD FLOW THROUGH THE LIVER. The branches of the portal vein spread out between the lobules as *interlobular veins*. Thence *sinusoids* converge on the *central vein*. The central veins drain into *sublobular veins* which unite to form *hepatic veins* which open into the i. vena cava. Small branches of the *hepatic artery* accompany the portal and interlobular veins, nourish the areolar sheaths and end in the sinusoids.

The *bile passages* conduct bile in the reverse direction (i.e., towards the porta). *Lymph vessels* run both with the portal vein and the hepatic veins.

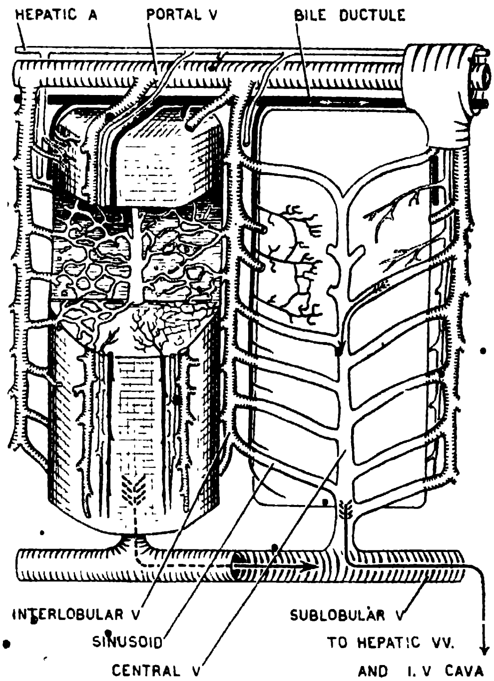


FIG. 45. Diagram of the blood flow through two lobules of the liver and of the course of the bile.

FUNCTIONS. As the blood moves leisurely through the sinusoids, the liver cells elaborate bile. They also regulate the amount of sugar (glucose) in the blood by removing the excess after a meal and temporarily storing it as glycogen. They also store vitamin A. They elaborate urea which the kidneys dispose of, also fibrinogen and heparin. The Kupffer cells are concerned with resistance to disease and with immunity, also with the destruction of effete red blood

cells and with the formation of bile pigment.

The Pancreas

The pancreas (Gk. pan = all; kreas = flesh), called the sweetbread in animals, has smooth polyhedral surface areas, each about 1 cm. in diameter, called *lobules*, separated from each other by fine areolar septa (*fig. 261*). It has an exocrine (external) and an endocrine (internal) secretion. The exocrine secretion is drained into the duodenum by a "herring-bone" duct system; that is, a large main duct runs through the gland and receives many fine ducts, but there are no ducts of intermediate size,—a distinguishing feature of the pancreas. The endocrine secretion enters the capillaries. Unlike the liver, where the same cells make both the exocrine and the endocrine secretions, here there is a division of labour.

The *exocrine secretion* is formed by pyramidal cells grouped around central lumina to form acini. It is the precursor of several ferments which act upon carbohydrates, proteins, and fats. Its liberation is under the control of a hormone, *secretin*, which is formed in the duodenal mucosa when the acid contents of the stomach flow over it. Secretin is absorbed into the blood stream and so passes by a round-about way to the acinar cells and provokes them to secrete. Stimulation of the vagus, however, also provokes them to secrete.

The *endocrine secretion* is formed by clusters of cells, the *islets of Langerhans*, varying greatly in size and number (200,000–1,700,000) and provided with an extensive capillary blood supply. These manufacture *insulin*, a hormone concerned with carbohydrate metabolism and employed in the control of diabetes.

The Spleen

The spleen is described here for convenience, but its association with the digestive system is incidental. It is a soft sponge filled with blood, about the size of a clenched fist, and coloured like the liver (*fig. 261*). It is covered with *peritoneum*, except at the hilum where vessels and nerves enter it, and it is free to move. It has a dense areolar *capsule* containing white fibres, elastic fibres and smooth muscle fibres which allow it to expand and contract. Supporting *trabeculae* of the same materials spread inwards from the capsule, and in them run branches of the splenic artery and vein. The spaces between the trabeculae contain a supporting *spongework* of reticular fibres and reticulo-endothelial cells. Long attenuated arteries pass from the trabecular arteries into the spongework which here and there is condensed around them in spindles or in spheres less than 1 mm. in diameter. These contain loosely imprisoned lymphocytes, and are called *Malpighian bodies*. The Malpighian bodies constitute the *white pulp* of the spleen. The remainder of the spongework contains many red cells, and so is called the *red pulp*. Dilated channels, termed *sinusoids*, permeate the red pulp and unite the arteries in the spongework to the trabecular veins.

THE BLOOD FLOW THROUGH THE SPLEEN. Regarding this there are several views. A modern view is that two different sets of channels connect the arteries in the spongework to the veins in the trabeculae (1) directly by capillaries controlled by sphincters at their entrances and (2) by sinusoids which have sphincters at their entrances and exits. When an entrance sphincter of a sinusoid

is open and an exit sphincter closed, blood plasma filters through the wall of the sinus into the pulp and the sinus becomes distended with blood cells; when both an entrance and an exit sphincter are open, the cells are swept on into the general circulation. About one sixth of the total volume of blood in the body can thus be stored in the spleen, which accordingly varies greatly in size.

FUNCTION. The white pulp produces lymphocytes; the sinuses store blood cells; the reticulo-endothelial cells break down the haemoglobin of effete red cells. and in so doing produce bile pigment, they also rid the blood of other debris, including probably effete blood-platelets and they are concerned with resistance to disease and with immunity.

The spleen is the largest of the lymphocyte producing organs, the chief depot of reticulo-endothelial cells, and the main storehouse of blood. It is not essential to life; in fact, in certain conditions it is advisable to remove it.

THE RESPIRATORY SYSTEM

Respiration is a chemical reaction essential to life; it involves the taking up of oxygen and giving off of carbon dioxide. In unicellular organisms this interchange of gases (O_2 and CO_2) takes place directly between the cell and the medium (which in all cases is water) in which the cell lives. But in a large multicellular organism, such as man, all cells, except the external ones, being removed from the surrounding medium (in this case air), require that the oxygen shall be brought to them from the exterior and that the carbon dioxide shall in turn be taken away. The transfer is made in two stages: the first stage is from the exterior via the air passages to the lungs, which act as a halfway house; the second stage is via the bloodstream to the watery medium (tissue fluids) which bathes the cells. Two systems, then, the respiratory and the circulatory, are here allied in the common purpose of permitting the individual cells to breathe (exchange gases) like unicellular organisms. The lungs are sponges filled with air; their septa being thin, moist, and membranous, allow transfusion of gases in solution. Being removed from the surface of the body they are, in a measure, protected from mechanical injury and from desiccation; moreover, the air reaching them is warmed and moistened by the air passages.

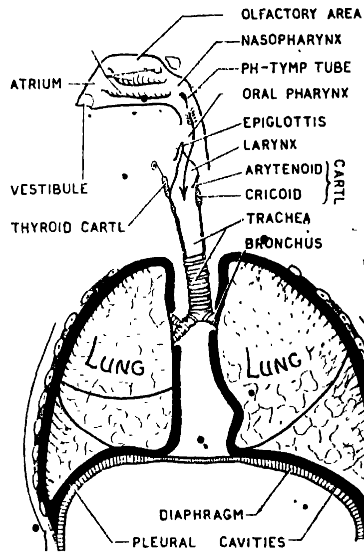


FIG. 46. Diagram of the respiratory system.

The respiratory system is developmentally an offshoot from the digestive system. The urinary and genital systems also are closely allied. Of these 4 tubular systems, the respiratory and digestive have absorptive functions; the urinary and genital have not—they are excretory. The walls of the digestive and respiratory passages, being thus exposed

to germs from without, are protected by a barrier of lymphocytes, such as the urinary and genital passages do not possess. The digestive system absorbs food; the respiratory system absorbs oxygen, the absorption taking place in the alveoli of the lungs. The products of digestion and the oxygen (which combines loosely with the haemoglobin pigment in the red blood cells to form oxyhaemoglobin) are conveyed by the blood to the tissues of the body where the products of digestion are oxidised and energy thereby released. The carbon dioxide, formed in the process, returns in the blood to the lungs and is there eliminated.

The respiratory system has two portions: (1) conducting, (2) respiratory. The *conducting portion,* or air passages, comprises:—the nasal cavities, pharynx, larynx, trachea, bronchi, and bronchioli; the *respiratory portion* comprises:—the alveolar sacs and alveoli of the lungs (*fig. 559*).

The Nasal Cavities, a right and a left, are separated from each other by a thin median partition, the *nasal septum.* The entrance to each cavity, called the *vestibule,* is lined with skin which bears hairs, sebaceous glands, and sweat glands. From the side wall of each cavity three downwardly curved shelves, the superior, middle, and inferior *conchae* (turbinals), conceal three antero-posteriorly running passages, the superior, middle, and inferior *meatuses.* Opening into the inferior meatus is the *tear duct* (naso-lacrimal duct); opening into the other meatuses are the orifices of large *air sinuses* (air cells). These sinuses invade the surrounding bones causing them to be large enough to carry 8 upper teeth on each side and yet remain light. The mucous membrane lining the nasal cavities and air sinuses is almost inseparable from the periosteum; hence, the two collectively are called *muco-periosteum.* The muco-periosteum covering the inferior concha, and to a lesser extent that covering the middle concha, contains dilatable *venous sinuses* which warm and humidify the inhaled air. The muco-periosteum has a covering of stratified ciliated epithelium with scattered goblet cells, and in it are mucous and serous glands, diffuse lymphoid tissue, and lymphoid follicles. The mucus catches inhaled dust and bacteria, and acts as a sterilising agent. The cilia waft the mucus, and the foreign matter entangled in it, backwards to the pharynx. The uppermost part (2 square cm. in each nasal cavity) of the medial and lateral walls is the *olfactory area.* Here the olfactory nerves, which stream through the thin perforated roof, *cribriform plate,* of the nasal cavity, end freely among the epithelial cells. This area is much more extensive in certain lower animals, such as the dog. The olfactory area is above the level reached by the air passing to and from the lungs, but eddies of air can be made to circulate here on sniffing, so that weaker stimuli may be appreciated. The *anterior nasal aperture* of each side is oval, mobile, bounded by soft parts (so it can dilate on taking a deep breath) and downwardly directed. The *posterior nasal aperture* of each side is oblong, rigid, bounded by four bony margins, and directed backwards towards the naso-pharynx (*fig. 725*) and it is functionally continuous with the latter.

The Pharynx is a fibro-muscular chamber, 5 inches long. It is attached above to the base of the skull; it lies in front of the upper six cervical vertebrae; and it is continuous below with the oesophagus. Communicating with it in front are the nasal cavities, mouth, and larynx. Accordingly, it is divisible into 3 parts (upper, middle, and lower), called the nasal, oral, and laryngeal parts respectively.

The nasal part or *naso-pharynx* is the backward extension of the nasal cavities, and it cannot be shut off from these cavities, but it can be, and is, shut off from the oral part by the soft palate and uvula during the act of swallowing. Were it not so, food would be forced from the oral part into nasal part and so to the nasal cavities—a person with a paralysed soft palate (e.g., after diptheria) may find this happen.

An air duct, the *pharyngo-tympanic tube* (auditory or Eustachian tube) opens by a funnel-shaped orifice on to each side of the naso-pharynx. Each tube is 1½″ long, and, by bringing the pharynx into communication with the tympanic cavity (middle ear) of the corresponding side, serves to keep the air pressure on the two sides of the tympanic membrane (ear drum) equal under changing atmospheric conditions. Normally the tubes are closed, but the act of swallowing opens them; hence, persons ascending or descending heights, as in an aeroplane, find relief through performing the movement of swallowing. The tubes also allow infection to spread from the naso-pharynx to the middle ear and beyond it to the air cells in the mastoid bone (*fig. 758*). The orifice of the tube is directed forwards towards the nasal cavity; so, fluid syringed along the cavity may enter the tube and carry infection to the middle ear.

A collection of lymphoid tissue, the *pharyngeal tonsil*, lies in the posterior wall of the naso-pharynx and extends laterally behind the orifices of the tubes. When enlarged, this tonsil is referred to as "adenoids". By obstructing the free flow of air through the naso-pharynx, adenoids cause mouth-breathing and collapse of the anterior nasal apertures. They may also obstruct the tubes, thereby preventing access of air to the middle ear with resulting indrawing of the ear drums and deafness. (*Fig. 745.*)

On each side of the entrance to the oral pharynx, and visible from the mouth, is a mass of lymphoid tissue, the size and shape of half a walnut, called *"the tonsil"* or the palatine tonsil. Its upper pole extends upwards from the side of the tongue into the soft palate; its lower pole cannot be seen unless the tongue is depressed.

The nasal part of the pharynx is, then, part of the respiratory passage; the oral part and the upper half of the laryngeal part are common to the respiratory and digestive passages.

The Larynx or voice box opens into the lowest part of the pharynx and is continuous below with the trachea. This box is kept rigid by a number of hyaline and elastic cartilages which are united by membranes. It is lined with mucous membrane internally and covered with voluntary muscles externally.

The chief cartilages of the larynx are: (a) The *thyroid cartilage* which resembles an angular shield, has two perpendicular *laminae* which meet in front in the median plane, the prominent upper end of the angle of meeting being conspicuous as the *laryngeal prominence* (Adam's apple). The posterior borders of the laminae are free and rounded, and below they grip and articulate with the cricoid cartilage as the knees of a horseman grip a saddle. (b) The *cricoid cartilage* is a complete ring expanded posteriorly into a lamina or plate and so resembles a signet ring; it keeps the lower part of the larynx perpetually open. (c) The *arytenoid cartilages* are paired, small, and pyramidal; their bases articulate with the upper border of the lamina of the cricoid, each articulation being capable of the movements of a universal (ball & socket) joint, such as the hip and shoulder. The *vocal*

cords extend from half way down the angle between the laminae of the thyroid to the anterior tips (vocal processes) of the arytenoid cartilages. When the arytenoids rotate medially the cords are approximated (adducted), as when talking and singing; and separated (abducted), as when taking a deep breath. (d) The *epiglottic cartilage* is shaped like a bicycle saddle, its stalk being attached to the angle of the thyroid cartilage just above the vocal cords.

The epiglottis was at one time thought to act as a lid that, during the act of swallowing, folded backwards over the entrance to the larynx in order to prevent the entry of food. However, during the act of swallowing; (a) the larynx rather is drawn upwards under shelter of the root of the tongue; (b) its entrance or upper aperture is closed by the sphincteric muscles that surround it and tilt the arytenoid cartilages forwards, and (c) the arytenoid cartilages are at the same time adducted and the *glottis* (i.e., space between the cords anteriorly and the arytenoids posteriorly) is closed. By these means food is prevented from entering the larynx. By palpating the thyroid cartilage while performing the act of swallowing, the larynx can be felt to be drawn upwards and forwards.

The Trachea or windpipe is an elastic tube over 4″ long, with a calibre equal to the root of the index finger. It is kept patent by about 20 C-shaped rings of hyaline cartilage which are open posteriorly. Involuntary muscle fibres, embedded in the elastic tube, unite the free ends of the C-shaped rings. Half of the trachea is in the neck, half in the thorax; and immediately behind it is the oesophagus. When you throw back your head you can readily feel the thyroid and cricoid cartilages rise, and perhaps feel the tracheal rings separate. It is the elastic tissue between the rings that allows the trachea so to lengthen. At the level of the sternal angle, 2″ below the suprasternal notch, the trachea bifurcates into a right and a left bronchus.

The Bronchi have the same structure as the trachea. After an oblique course of 2″, each enters the respective lung at the hilum and descends towards the base, giving off anterior and posterior branches; these in turn branch and rebranch like a tree. Within the lung the C-shaped rings give place to flakes of hyaline cartilage which surround the tube. When the bronchi are reduced to the diameter of 1.0 mm., they are called *bronchioles*. Here the cartilage ceases; just beyond, the mucous glands cease and the ciliated cells become cubical. Around the bronchi and bronchioles involuntary muscle fibres are wound spirally. The terminal bronchioles divide into a number (2 to 11) of alveolar ducts which end in dilated air sacs, *alveolar sacs*. The walls of these sacs being themselves sacculated, resemble a bunch of grapes, and hence they are called alveoli (L. alveolus = a bunch of grapes) (*fig. 559*). Adjacent alveolar sacs are practically contiguous—between them there is room only for a close-meshed network of capillaries through which the blood cells hurry in single file giving off CO_2 and taking up O_2 from the alveoli on each side with a resulting change in the colour of the blood from relatively blue to red. This being the aim and object of respiration, the alveoli are the essential constituents of the lung. Since alveoli also occur on the bronchioles immediately preceding the alveolar ducts, they are termed *respiratory bronchioles*.

The Lungs, a right and a left, are spongeworks of elastic tissue which on section and in consistence resemble rubber sponges. In this highly elastic

framework the bronchi and the companion branches of the pulmonary artery and vein ramify, the bronchi conducting air to and from the alveoli, the vessels conducting blood.

The lungs occupy the conical thorax, each lung forming half a cone. The right lung is divided by two complete fissures into three separate lobes; the left is divided by one fissure into two lobes.

Each lobe of each lung has a delicate and inseparable "skin", the *visceral pleura.* This is a perfectly smooth, moist, serous membrane, identical in structure and in origin with peritoneum, i.e., a fine areolar sheet with a surface of squamous (mesothelial) cells. Another layer of pleura lines the ribs, diaphragm, and mediastinum (containing the heart); this is *parietal pleura.* Between the visceral and parietal layers of pleura there is a potential space, the *pleural cavity,* best explained by fig. 530. It allows the lung to expand and contract without friction.

The Respiratory Act has 2 phases—inspiration and expiration. On inspiration the diaphragm descends, thereby increasing the vertical diameter of the thorax; and the ribs rise from a sloping to a more horizontal position, thereby increasing the antero-posterior and the side-to-side diameter, as you can determine by palpation. The atmospheric pressure is 14.7 lbs. to the square inch at sea level; therefore on enlarging the thorax (inspiration) air rushes down the trachea and bronchi into the lungs so that they expand, thereby avoiding the formation of vacua in the pleural cavities. Expiration is largely a matter of elastic recoil; that is, the highly elastic tissue contracts, the stretched abdominal muscles act like an elastic belt on the abdominal contents forcing the diaphragm upwards; and the cartilages of the ribs, which underwent twisting during inspiration, now untwist.

The respiratory act has aptly been likened to fire-bellows in action, the thoracic cage being the framework of the bellows, the trachea the nozzle.

As the table shows, during quiet respiration about 500 c.c. of air are inspired and expired. On full inspiration about an extra 2500 cc. can be taken in; and on full expiration an extra 1000 cc. can be forced out. Even then there remain in the alveolar sacs, trachea, and bronchi about 1000 cc. which cannot be expelled.

Total capacity	2500	Complemental air	Vital capacity
	500	Tidal air	
	1000	Supplemental air	
	1000	Residual air	

Nerve Supply. The respiratory centre is located diffusely in the reticular formation of the medulla oblongata. If the centre is destroyed or if the spinal cord between the centre and the origin of the phrenic nerves, which supply the diaphragm, is severed, respiration ceases. The normal stimulus to the centre is the excess CO_2 in the circulating blood. Efferent impulses descend from the centre to the nuclei of the phrenic (C. 3, 4, 5) and intercostal nerves (Th. 1–11) in the spinal cord and along these nerves to the diaphragm and intercostal muscles, causing them to contract. When the lung is distended, afferent impulses ascending in the vagus nerve inhibit further inspiration and provoke expiration.

The bronchial muscles (circular) are made to contract by the vagus nerves and to relax by the sympathetic, hence in asthma the spasms of these muscles are relieved by adrenalin.

Epithelial Surfaces. The respiratory passages as far as the bronchioles of 1 mm. in diameter are lined with stratified

columnar, ciliated epithelium containing scattered goblet cells. In the mucous membrane are mucous and serous glands, also lymphoid tissue both diffuse and aggregated.

In the protective mucus that lines the larynx, trachea, and bronchi inhaled dust and other foreign material is caught and entangled. The cilia cause the lining tube of mucus to move ever upwards, like a moving carpet or escalator, to the entrance of the larynx where it spills over into the pharynx and is swallowed. The other method of expelling foreign material is by coughing. The lymphoid tissue also is defensive against foreign invasion.

Exceptional Areas. (1) The vestibule of the nose is lined with skin, possessing hairs, sweat glands, and sebaceous glands; (2) areas subjected to pressure or friction, where cilia could not survive, are protected by stratified squamous epithelium, viz.—(a) the parts of the upper surface of the soft palate and uvula which are applied to the pharyngeal wall during swallowing; (b) areas against which the food comes into contact, namely, the entire oral and laryngeal parts of the pharynx and also the dorsal aspect of the upper half of the epiglottis; (c) the vocal cords, which vibrate and strike each other; (3) the terminal and respiratory bronchioles, whose epithelium is cubical; (4) the alveoli, whose lining epithelium is by some thought to be partly squamous and partly cubical; by others, absent; (5) the olfactory (smell) epithelium

The cilia in the nasal cavities work backwards towards the pharynx; those in the trachea and bronchi upwards towards the pharynx; those in the air sinuses spirally around the walls to the orifices.

Coughing is a defensive act, an attempt to blast a foreign body out of the trachea and larynx. Thus, following an inspiration, the vocal cords are approximated and kept approximated (adducted) while the movements of expiration are begun; the cords then suddenly relax (abduction), whereupon by the force of the air the irritant is blown out of the larynx. The afferent impulses travel in the internal laryngeal branch of the vagus when the source of irritation is above the vocal cords and in the recurrent laryngeal branch when below. Coughing may also result from inflammation of the pleura, but as there is then nothing to be expelled, the coughing is profitless and it may be wise to arrest it by means of drugs.

Sneezing likewise is a defensive act, an attempt to blast a foreign body out of the nasal cavity. The act is preceded by a deep inspiration and the mouth usually kept closed during forceful expiration. The afferent impulses travel in the maxillary branches of the trigeminal nerve.

THE URINARY SYSTEM

The urinary system and the genital system are closely associated in their development and are commonly described together as the *urogenital system.* In the human male, but not in the female, the urethra serves as an outlet for the products of both systems.

The urinary system comprises the following parts:

(1) Kidneys } bilaterally paired structures.
(2) Ureters }

(3) Bladder } median, unpaired structures.
(4) Urethra }

The *kidneys* excrete urine. This passes down two muscular tubes, one on each side, the *ureters,* into a muscular reservoir, the *urinary bladder,* where it is stored until such time as it is convenient to discharge it by the *urethra.*

Kidneys. Each of the two kidneys is of conventional kidney-shape, is about

4½ inches long and weighs about 4½ ounces. Its function is to keep the composition of the blood plasma constant. This it does by removing the excess of water and the waste products, especially those resulting from the metabolism of nitrogenous substances. It also maintains the alkalinity of the blood (a) by manufacturing ammonia, which combines

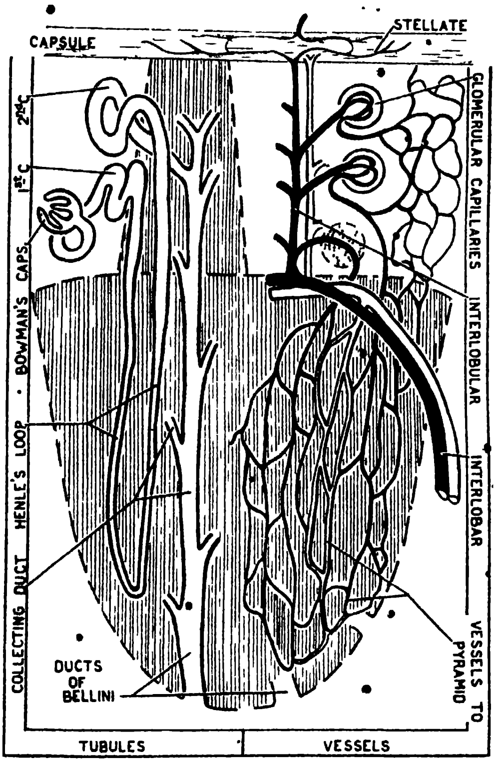


FIG. 47. Diagram of the tubules and blood supply of the kidney. (See also fig. 260.)

with the surplus acid radicle of the salts of the blood to form ammonia salts, which are then excreted by the kidneys, whereas the bases are retained; and (b) by excreting NaH_2PO_4 instead of Na_2HPO_4. To the former salt the urine owes its acid reaction.

STRUCTURE (*fig. 47*). A kidney contains about 1.000,000 microscopical units. Each unit or *nephron* has two parts (1) a *glomerulus*, and (2) a *uriniferous tubule.*

A glomerulus (dim. L. glomus = a ball) is a spherical bunch of looped capillaries about 200μ in diameter, which invaginates the expanded blind end of a uriniferous tubule, called *Bowman's capsule*, much as the lens of the developing eye invaginates the optic vesicle to form the optic cup, but with this difference—the invaginated layer of the capsule covers the individual loops of capillaries and dips into the crevices between them, thereby creating an extensive surface, estimated to be 0.3813 sq. millimetres per glomerulus or 0.3813 sq. metres per kidney (M. H. Book). The two layers of Bowman's capsule, outer and inner or invaginated, and the glomerulus are known as a *Malpighian corpuscle,* but the term is variously applied. Malpighi, who first saw the corpuscles, likened them to apples hanging from a tree. The capsule is succeeded by the 1st. (proximal) convoluted tubule, the descending and ascending limbs of Henle's loop, the 2nd. (distal) convoluted tubule and finally the junctional tubule which discharges into a system of collecting tubules. About a dozen collecting tubules open on to the papilla of each pyramid (*fig. 287*) and discharge their contents into the pelvis of the ureter. Each named part of the tubule has a distinctive epithelium and, accordingly, a different function. The glomeruli and the convoluted tubules occupy the labyrinth of the kidney; the limbs of Henle's loops and the collecting tubules occupy the pyramids.

VESSELS. The renal vessels are exceptionally large. The artery generally breaks up into 3 *main branches,* of which 2 pass in front of the pelvis and 1 behind it. These send branches into the renal columns, situated between the pyramids, and, because the pyramids are spoken of as the lobes of the kidney, they are

called *interlobar arteries*. At the junction between the medulla and cortex these divide into branches (arcuate arteries) which curve between these two parts. From these branches, *interlobular arteries* pass radially towards the capsule, running between the medullary rays. Each interlobular artery gives off many short arterioles, vasa afferentia, which pass at right angles into the labyrinth where the glomeruli lie. Each *vas afferens* enters a glomerulus and there branches to form capillary loops, as described above. These reunite and leave the glomerulus as a single vessel, the *vas efferens*, which is of smaller lumen than the vas afferens. The vas efferens now breaks up into capillaries which ramify among the convoluted tubules. These reunite to form venules, which in turn become interlobular, (arcuate), interlobar and main veins. The pyramids are supplied by long parallel meshed vessels, *arteriolae rectae*, which proceed from the glomeruli situated near the border zone.

Note: (a) The renal artery is disproportionately large; its branches are large; and each vas afferens is larger than the corresponding vas efferens. All this makes for high arterial pressure within the glomeruli. (b) The blood flowing through the renal artery passes first through the glomerular capillaries, which are filters, and then through a second set of capillaries. To this the fine twigs that leave the artery in the renal sinus for the supply of the ureter, the perirenal fat and the capsule of the kidney are exceptions; so are the terminal twigs (stellate arteries) of the interlobular arteries that radiate under the capsule, and a few arteriolae rectae to the pyramids, which pass through atrophic glomeruli (*fig. 47*).

The interlobular veins begin under the capsule as stellate veins and may be seen on stripping it off. The tributaries of the renal veins anastomose freely.

Urine is not a secretion, but a concentrated filtrate, the glomeruli doing the filtering, the tubules the concentrating. Since the blood is circulating under pressure through the glomerular capillaries, water, salts in solution and substances of small molecular size filter through into Bowman's capsule. Of course, the blood cells remain within the blood vessels; so do the blood proteins, for they are of large molecular size, and there they exert an osmotic pressure which tends to retain water and dissolves substances within the blood stream. For the "excretion" of urine the blood pressure must exceed the osmotic pressure within the vessels. The quantity of filtrate that passes daily into Bowman's capsule is estimated to be about 100 litres, but an average amount of urine voided daily is a little more than one litre. All but a fraction, then, of the water filtered is reabsorbed as it passes down the tubules and is restored to the blood. Some constituents of the filtrate (e.g., glucose, sodium chloride) are entirely reabsorbed; others (e.g., urea, uric acid, and phosphates) are reabsorbed to a slight extent; others (e.g., creatine and sulphates) are not reabsorbed.

From the kidney the urine is propelled by peristaltic action along a ten inch muscular tube, the *ureter*, into a hollow muscular reservoir, the *urinary bladder*. Through a urethroscope introduced into the bladder, jets of urine are seen to leave the urethral orifices two or three times a minute. The bladder has a capacity of ½ to 1 pint. From it a fibro-muscular tube, the *urethra*, leads to the exterior of the body. It is about 6″ to 8″ long in the male, 1¼″ in the female. At the junction of the blad-

der and urethra (i.e., at the neck of the bladder) the bladder is guarded by a sphincter of involuntary muscle, the *sphincter vesicae,* and beyond this (i.e., between the fasciae of the urogenital diaphragm) it is guarded by a sphincter of voluntary muscle, the *sphincter urethrae.*

Micturition. As urine gradually collects within the bladder, the muscle wall adapts itself to the increasing volume without appreciable increase in internal pressure until 200 to 300 cc. have collected. The internal pressure then begins to rise and rhythmical contractions of the bladder wall begin. These, increasing, culminate in a strong reflex contraction of the wall and an associated relaxation of the sphincter, and so the bladder is emptied. Though micturition is essentially a reflex act, it can be, and is, both initiated and inhibited at will, until a suitable occasion presents.

Nerve Supply. THE KIDNEY. The strong clinical evidence is that the kidney receives sympathetic fibers that pass over the smallest splanchnic nerve and the gray rami of ganglion L. 1 to the renal plexus and thence along the renal vessels to the kidney. The nerve fibers are vasoconstrictor, vasodilator, and afferent. Cutting posterior nerve roots of T. 12, L. 1, and L. 2 relieves renal pain. (White and Smithwick.) A denervated kidney continues to excrete normal urine.

THE URETER. In its upper part the ureter receives nerve fibers from the renal and intermesenteric plexuses; in its lower part from the pelvic plexus (inf. hypogastric plexus) at the side of the bladder, vesicle and prostate; and in its middle part from the hypogastric plexus and hypogastric nerve in association with the spermatic plexus. (Mitchell.) Its spinal connections are L.1 and 2. The peristalsis of the ureter is not disturbed by lumbar sympathectomy, in fact, by the withdrawal of inhibitory sympathetic influences the functions of a dilated (hydronephrotic) ureter and of a dilated colon (megacolon) are improved.

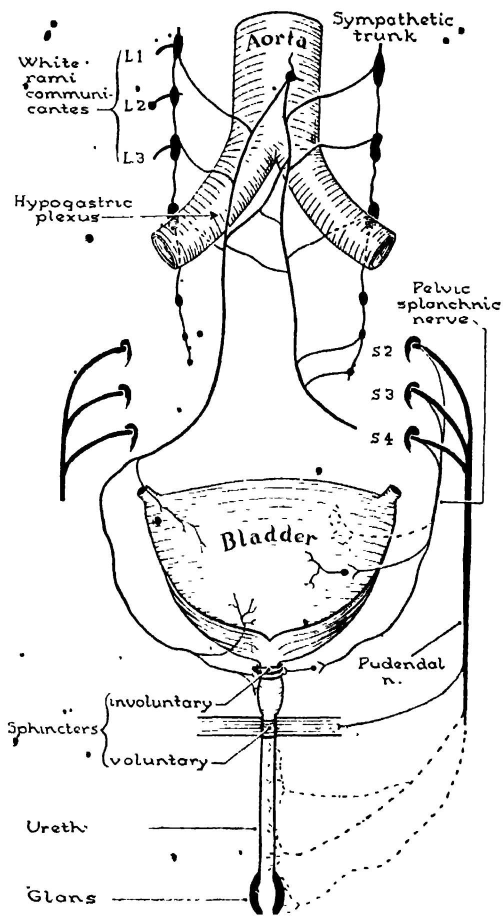


FIG. 48. Diagram of the nerve supply of the bladder and urethra.

Parasympathatic. Vagal fibers via the coeliac plexus may be supposed for the kidney and upper part of the ureter, and pelvic splanchnic nerve fibers for the lower part.

THE BLADDER AND URETHRA (*fig. 48*).

Parasympathetic. The pelvic splanchnic nerves (nervi erigentes; S. 2, 3, 4) are the motor nerves to the bladder; when

they are stimulated the bladder empties, the blood vessels dilate, and the penis becomes erect. They are also the sensory nerves to the bladder.

Sympathetic, through the hypogastric plexus (presacral nerve; Th. lower, L. 1, 2, 3) is motor to a continuous muscle sheet comprising the ureteric musculature, the thetic is also vaso-constrictor and to some slight extent it is sensory to the trigonal region.

The pudendal nerve is motor to the sphincter urethrae and sensory to the glans penis and the urethra.

It would seem that the sympathetic supply to the bladder has a vaso-con-

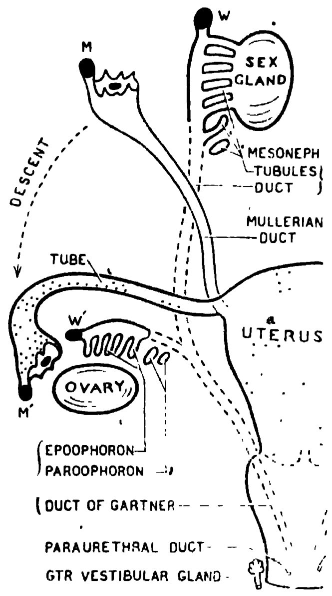


FIG. 49
Diagram of the female genital system (front view).

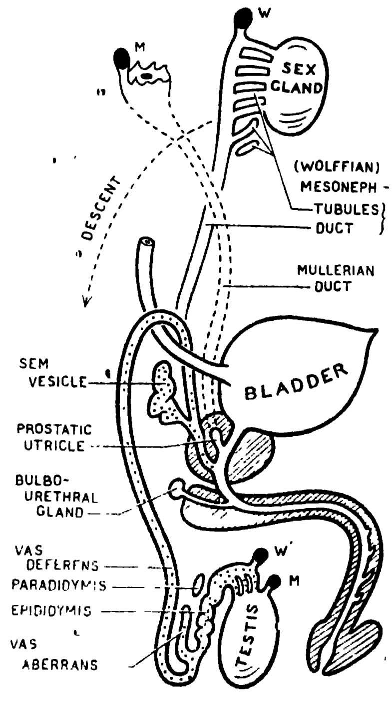


FIG. 50
Diagram of the male genital system (side view).

The parts of the Mullerian duct in the male and of the mesonephric duct in the female, shown in broken lines, disappear. In the upper halves of both figures the parts are shown in their early foetal or indifferent state. M = Mullerian appendage; W = Wolffian (mesonephric) appendage.

trigonal muscle, and the muscle of the urethral crest. It also supplies the muscle of the epididymis, vas deferens, seminal vesicle, and prostate. When the plexus is stimulated, the seminal fluid is ejaculated into the urethra but is hindered from entering the bladder perhaps by the muscle sheet which is drawn towards the internal urethral orifice. The sympa-

strictor and a sexual effect and that as regards micturition it is not antagonistic to the parasympathetic supply. (Learmonth; Langworthy and others.)

THE GENITAL SYSTEM

The male and female organs of reproduction, though differing in appearance before the time of birth, are funda-

mentally the same, and in early foetal life are very similar. In both sexes they pass through an indifferent stage during which there is a pair of parallel ducts—the Wolffian or mesonephric and the Mullerian or paramesonephric—on each side of the body. In the male, the Wolffian ducts are utilised as genital ducts and the Mullerian ducts largely disappear or remain vestigial; in the female the converse is true (*figs. 49, 50*).

Each sex has (1) a symmetrical pair of reproductory or sex glands, which produce germ cells—spermatozoa in the male and ova in the female; (2) passages through which these germ cells find their way to the exterior of the body; (3) vestigial parts (well developed in the opposite sex); (4) accessory glands; and (5) external genitals or pudenda.

Corresponding Male and Female Parts

	MALE	FEMALE
Sex Gland	Testis	Ovary
Passages and Vestigial Parts	Epididymis . . .	*Appendix (W)*, *Epoophoron*, *Paroophoron*
	Vas Deferens . .	*Duct of Gartner*
	Urethra	——————
	Appendix (M).	Uterine Tube
	Prostatic Utricle .	Uterus
	——————	Vagina
Accessory Glands	Seminal Vesicle .	——————
	Prostate	Para-urethral Glands
	Bulbo-urethral Gland	Greater Vestibular Gland
	Urethral Glands .	Lesser Vestibular Glands
External Genitals	Penis, Scrotum	Pudenda

The Male Genital System

The Testes or male sex glands, one on each side, lie in the scrotum. (*See figs. 209, 210.*) Each testis is oval, slightly flattened from side to side, and 1½″ long. Like the eyeball it has a thick, white, inelastic, fibrous outer covering, the *tunica albuginea*. Within this covering are about 250 delicate pyramidal compartments, each containing from 1 to 3 greatly convoluted threadlike tubules, the *seminiferous tubules*, which are from 1 to 2 feet long, so the total length of these in each testis is about 250 yards. These tubules open into an anastomosing network, the *rete testis*, near the posterior border of the testis. The seminiferous tubules produce *spermatozoa* or male gametes—little tadpole-like cells with a head much smaller than a red blood cell, a body of the same length, and a long motile tail.

The testis is covered in front and at the sides by a bursal sac, the *tunica vaginalis testis*, which before birth was continuous with the peritoneal cavity.

The Ducts of the Testis. From 6-12 fine coiled tubules, the *efferent ductules*, each about 8″ long, lead out of the upper part of the rete testis into the *canal of the epididymis*. This canal, though about 20 feet long, is so folded as to form a compact body, the *epididymis* (Gk. epi = upon; didumos = a twin; i.e., the testes are twins), which caps the upper pole of the testis and is applied to its posterior border. The *vas deferens* (ductus deferens) connects the canal of the epididymis to the urethra, and so leads away from the testis. It is about 18″ long. It ascends first (behind the testis) along the medial side of the epididymis, and then through the upper part of the scrotum to the abdominal wall. This it pierces obliquely. Continuing, it runs under cover of the peritoneum to the base of the bladder, and then descends between the bladder and the rectum. Its terminal ¾″, the *ejaculatory duct*, pierces the prostate and opens into the urethra close to its fellow, about an inch beyond the bladder. From this point onwards

the male urethra is the common duct of the urinary and genital systems.

STRUCTURE. The efferent ductules are lined with ciliated epithelium and mucous-secreting cells. The canal of the epididymis and the vas have a circular muscle coat with longitudinal muscle fibres both inside and out. The vas feels like a whipcord because the muscle is so thick and the lumen so small; the epididymis feels soft because the muscle is thin and the lumen large. Each has a mucous coat. The cells lining the canal of the epididymis are columnar with non-motile ciliated processes which discharge a mucoid secretion; those in the vas are cubical. The part of the vas behind the bladder, the *ampulla of the vas*, is dilated, thin-walled and easily torn. Within it are septa and secretory outpouchings.

Accessory Glands. The SEMINAL VESICLES, one on each side, are tubular outgrowths from the ampullary ends of the vasa, which they resemble in structure. Each vesicle has outpouchings and short branches and is 2″ long, but when unravelled, it is 3 to 4″ long (*see figs. 324, 346*). The vesicles are absent in some animals (e.g., the dog), large in others. They secrete a yellowish sticky liquid.

THE PROSTATE GLAND (Gk. pro = before, istanai = to stand), the size and shape of a large chestnut, surrounds the first 1¼″ of the urethra just beyond the bladder. It is partly glandular, partly muscular and partly fibro-areolar. It secretes into the urethra an opalescent liquid, free from mucus. It is pierced by the ejaculatory ducts.

THE BULBO-URETHRAL GLANDS (of Cowper), the size of a pea, lie one on each side of the membranous urethra. Their ducts are 1″ long and open into the spongy urethra. They secrete a mucus-like substance.

THE GLANDS OF THE URETHRA. At places the stratified columnar epithelium lining the urethra gives place to (a) single *mucous cells*, (b) mucous cells in clusters at the bottom of slight depressions or *lacunae*, and (c) mucous cells lining glands with short ducts, the *glands of Littré;* these are commonest on the dorsal wall.

The Penis (L. penis = a tail) is the male organ of copulation (*see fig. 310*). It comprises 3 parallel fibrous tubes, 2 paired and 1 unpaired, which are filled with cavernous tissue and are enclosed in a single loosely-fitting tube of skin and subcutaneous tissue. The paired tubes, the right and left *corpora cavernosa penis*, are fused side by side. In front they present a rounded end; behind they diverge into right and left *crura* (L. crus = a leg) which are firmly attached to the pubic arch. The c. cavernosa are the "skeleton" of the penis. The unpaired tube, the *corpus spongiosum penis* (c. cavernosum urethrae) occupies a groove below the united c. cavernosa; it is traversed by the urethra. Its expanded hinder end is fixed to the membrane (perineal membrane) which stretches between the sides of the pubic arch; its expanded anterior end, the *glans* (L. glans = an acorn), fits like a cap on the ends of the c. cavernosa. The redundant skin covering the glans is the *prepuce*. The operation of circumcision consists in removing the prepuce.

The Scrotum is the bag of skin and laminated subcutaneous tissue in which the testes lie. Like the penis it is free from fat, but it contains a layer of smooth muscle, the *dartos*, which causes wrinkling of the skin when cold. Originally there were two scrota, a right and a left; the

skin of the scrotum now forms a single common pouch; the dartos and subcutaneous tissues continue to form a right and a left pouch, but their medial walls have fused to form a median septum.

Semen (L. = seed) is composed of spermatozoa suspended in the secretions of the ducts of the testes and of the accessory glands. The spermatozoa are formed in the testis, whose walls are inelastic; and they overflow into the efferent ductules, whose cilia waft them on into the epididymis with whose secretion they mix and where they are stored until emitted. The number of spermatozoa in an emission is estimated to be 300,000,000; but only one ovum is shed by an ovary each month.

Erection. Stimulation of the pelvic splanchnic nerves produces erection of the penis hence the term "nervi erigentes" originally given to these nerves – by causing dilatation of the arteries and cavernous tissue of the penis and constriction of the veins. In the normal reflex act the afferent limb is the pudendal nerve (S. 2, 3, 4); the efferent is the pelvic splanchnic (S. 2, 3, 4) (*see fig. 48*). Apart from psychic influences, this is brought about by stimulation of the pudendal nerve endings, free and encapsuled, in the glans penis. The fibres of the pelvic splanchnics pass through the prostatic nerve plexus and under the pubic arch to the vessels of the penis. **Ejaculation.** The impulse spreading, sympathetic nerves are stimulated to cause closure of the internal urethral orifice, to set up peristaltic waves which empty the epididymis and propel its contents through the vas to the urethra, and to empty the seminal vesicles and prostate of their secretions. The segment is L. 1. The path is probably via the inter-mesenteric and hypogastric plexuses, because the usual operation for removal of the lumbar sympathetic does not impair ejaculation, but removal of the hypogastric plexus does so permanently. (Learmonth). By causing the Bulbospongiosus to contract the pudendal nerve is responsible for emptying the spongy urethra.

The Female Genital System

The Ovaries or female sex glands, one on each side, lie on the side wall of the pelvis (*see fig. 360*). Each ovary is a solid body about half the size of a testis and more flattened. It has an attached border; elsewhere it projects into the peritoneal cavity. It is covered, however, not with squamous peritoneal cells but with a cubical epithelium (germinal). Its surface is scarred and pitted due to the shedding of ova At birth each ovary contains about 200,000 (immature) ova. From puberty to the end of the reproductive period (15th to 45th year) an ovum is shed into the peritoneal cavity about once a lunar month, and, having no motive power, there it lies at large. In all about 400 ova are shed; the rest are absorbed in the ovary.

The Ducts or Passages that conduct the ova to the exterior of the body are the uterine tubes, which are paired, and the uterus and vagina, which are unpaired. The *uterine or Fallopian tube* is about $4\frac{1}{2}''$ long, is as large as a pencil, lies in the free edge of a fold of peritoneum, the *broad ligament*, and takes a twisted course from ovary to uterus. Its ovarian end opens by a trumpet-shaped mouth (infundibulum) into the peritoneal cavity beside the ovary, and from it finger-like processes (fimbriae) project. Its other end opens into the cavity of the uterus.

Structure and Function. It has

thin outer longitudinal and inner circular muscle coats, a mucosa thrown into numerous longitudinal folds, and a lining of columnar cells in part ciliated, in part secretory. When an ovum is about to be shed the fimbriated mouth of the tube is turned and likely applied to the ovary ready to receive the ovum. Peristaltic action propels it along the tube, the cilia perhaps helping, and the secretion of the tube nourishing. In the tube the ovum may be met and fertilised by a spermatozoon, which is able to propel itself through the uterus in about 6 hours.

The Uterus is a thick-walled, hollow, muscular organ placed near the centre of the pelvis and projecting into the peritoneal cavity between the bladder and the rectum (*see fig. 355*). It is shaped like an inverted pear, somewhat flattened from before backwards so that its cavity is collapsed, and is 3″ long. Above, a uterine tube opens into it on each side; below, it opens into the vagina. The upper 2″ are the *body;* the lower 1″ is the *cervix;* the part of the body above the entrance to the tubes is the *fundus.* Its function is to harbour a fertilised ovum for nine months. During the first two months the ovum is in the indifferent or embryonic stage; during the last seven it is in the formed or foetal stage.

STRUCTURE. Under a *peritoneal covering* there is a coat, ½″ thick, of interlacing *smooth muscle fibres* which by contracting not only expel the uterine contents (e.g., foetus and placenta) but also compress the branches of the uterine vessels which pass between them, and so arrest postpartum haemorrhage. Internally there is a thick *mucous coat* (endometrium) pervaded by tubular pits. The mucous coat and the pits are lined with a columnar epithelium, largely ciliated. In the cervix the muscle fibres are chiefly circular, forming, as it were, a sphincter; the mucous membrane possesses branched mucus-secreting glands, and is lined with an epithelium which is columnar except at the external orifice of the cervix where it is stratified squamous. The peritoneum covering the body and fundus stretches from each side of the uterus as a fold, the *broad ligament,* that rises from the pelvic floor, extends to the side wall and has in its upper free edge the uterine tube.

The Vagina (L. = a sheath) is a relatively thin-walled collapsed tube, about 3½″ long. The cervix projects into its upper end; below, it opens into the pudenda. It has a coat of smooth muscle fibres, mostly longitudinal except below, where many are circular, an outer fibro-areolar coat, and a mucous membrane which is thrown into ridges or rugae and is lined with stratified squamous epithelium. The vagina having no glands, any mucus present within it comes from the cervix.

Accessory Glands. THE PARAURETHRAL GLANDS (paired) have ducts which open at the side of the urethral orifice. THE GREATER VESTIBULAR GLANDS (of Bartholin) are paired like their homologues in the male, the bulbo-urethral glands, and like them have long ducts, well seen in fig. 317. THE LESSER VESTIBULAR GLANDS are a few small mucous glands surrounding the urethral orifice.

The External Genitalia (pudenda) have their homologous parts in the male, see page 316.

Nerve Supply. The ovaries, like the testes, are supplied by T. 10; the fibres travel with the ovarian vessels through the suspensory ligaments, and some of them supply the *uterine tubes.* The *uterus* is supplied by the hypogastric plexus and the pelvic splanchnic nerves which pass through the utero-vaginal plexuses in the

broad ligaments. The afferent fibers from the fundus pass through the hypogastric plexus and enter the cord via T. 11, 12; those from the cervix pass to the sacral nerves. The *vagina* is supplied by the utero-vaginal and vesical plexuses and by fibres direct from the pelvic splanchnic.

THE SKIN AND ITS APPENDAGES AND THE FASCIAE

The skin or cutis has for appendages: hairs, nails, sweat glands, and sebaceous glands.

Do not misconceive the skin to be merely an envelope wrapped around our bodies like paper around a parcel. It is, indeed, a wrapping but it is more than a wrapping—it is one of our most versatile organs. As an *envelope* it has admirable properties: being waterproof it prevents the evaporation and escape of tissue fluids; it becomes thick where it is subject to rough treatment; it is fastened down where it is most liable to be pulled off; it has friction ridges where it is most liable to slip; "—even with our ingenious modern machinery we cannot create a tough but highly elastic fabric that will withstand heat and cold, wet and drought, acid and alkali, microbic invasion, and the wear and tear of three score years and ten, yet effect its own repairs throughout, and even present a seasonable protection of pigment against the sun's rays. It is indeed the finest fighting tissue" (Whitnall). As an *organ* it is the regulator of the body temperature; it is an excretory organ capable of relieving the kidneys in time of need; it is a storehouse for chlorides; it is the factory for antirachitic vitamin D (ergosterol) formed by the action of the ultraviolet rays of the sun on the sterols in the skin, and necessary for the mineralisation of bones and teeth; and it is the most extensive and varied of the sense organs.

In an average adult man the skin covers a body surface of 1.7 sq. metres. At the orifices of the body it is continuous with the mucous membranes. The skin, somewhat modified, forms the conjunctiva and the outer layer of the ear drum.

The Skin or cutis (L. cutis = skin) has two chief parts (*fig. 51*): (1) the

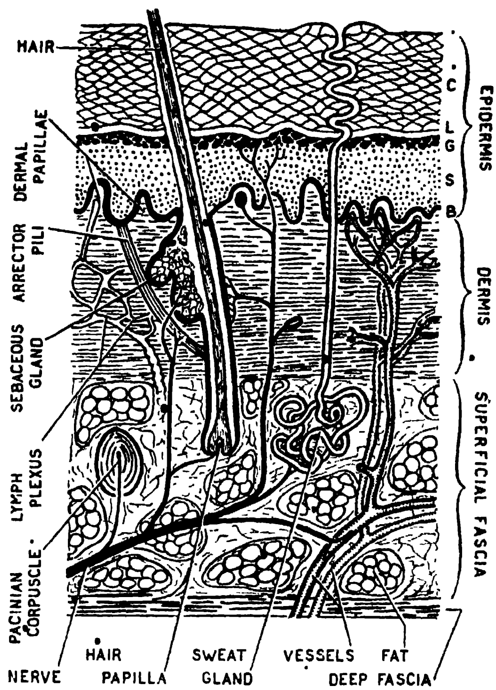


FIG. 51. Section of thick skin, superficial fascia and deep fascia. C = stratum corneum; L = stratum lucidum; G = stratum granulosum; S = germinative layer; B = basal layer of columnar cells. (After Appleton, Hamilton and Tchaperoff.)

dermis (Gk. derma = skin) and (2) the epidermis. THE DERMIS (true skin, cutis vera or corium) is of mesodermal origin. It is a feltwork of bundles of white fibres and of elastic fibres. Superficially the feltwork is of fine texture; deeply it is coarse and more open and its spaces contain pellets of fat, hair follicles, sweat glands and sebaceous glands. It is in general 1 to 2 mm. thick, but is thicker

on the palms and soles and back, and is thinner on the eyelids and external genital organs. The spaces in the feltwork are lozenge-shaped, hence a needle puncture does not remain a round hole. The long axes of the lozenges are differently directed in different parts, usually being parallel to the lines of tension of the skin. A cut across the long axes of these lines, *Langer's lines*, will gape. It is due to the presence of elastic fibres that the skin, after being stretched or pinched into a fold, returns to normal. Dermis, when tanned, is called leather.

THE EPIDERMIS is a non-vascular stratified epithelium of ectodermal origin. The deeper layer, the *germinative layer*, is living. It consists of several strata of polyhedral cells resting on a single stratum of columnar cells. These strata may show mitotic figures. The superficial layer, the horny layer or *stratum corneum*, is dead. It consists of several strata of dry, flattened, scaly cells without visible nuclei. The surface cells are perpetually being rubbed away and are perpetually being replaced by cells of the germinative layer. Where the epidermis is thick, notably on the palms, soles and back, there are two intermediate layers a *granular* and a *clear*. The granular layer or *stratum granulosum* lies next the germinative layer. It consists of cells 2 to 3 deep, or merely of a few scattered cells, which are nucleated and contain granules of a waxy material (eleidin). This layer is transformed into a clear one, the *stratum lucidum*, in which the cell outlines are indistinct and the granules run together to form a horny material (kerato-hyaline).

Finger-like processes of the dermis, *papillae*, protrude into the epidermis anchoring it in the same manner as the tubercular surface of the diaphysis of a bone anchors the epiphysis. These papillae are specially long on parts devoid of hair, e.g., the red of the lips, nipples, and external genitals; on the palms and soles they are arranged in double rows under the friction ridges (*see fig 129*).

The horny layer is thick on the palms and soles even at the time of birth; pressure and friction at any site provoke it to thicken.

PIGMENTATION is due to the presence of (a) melanin granules in the columnar cells of the germinative layer—in negroes these granules are found in all cells of the epidermis— and (b) branched pigment cells, melanoblasts, which lie deep to the columnar cells and send processes between them.

The Nails are thickenings of the deeper layers of the stratum corneum. A nail has a free end which projects, a root which extends proximally deep to the overhanging nail fold, two lateral borders, a free surface and a deep one. The white crescent appearing distal to the nail fold is the lunule. The deep surface rests on and adheres to the *nail bed*. This largely consists of bundles of white fibres which attach the dermis to the periosteum. The dermis is covered with stratum granulosum into which longitudinal vascular ridges project. On cross-section these have, of course, the appearance of papillae.

Growth takes place at the root and from the bed as far distally as the lunule; beyond this the nail probably slides distally on its bed, adhering to it. Toxins, arising in an acute illness, temporarily arrest the growth of the nails (as they do of the bones, *see fig. 15*) and a transverse ridge appearing on each nail when growth is resumed is evidence of a past illness. Seeing that the average rate of nail growth is 0.1 mm. a day or 3 mm. a month (i.e., about $1\frac{1}{2}''$ a year) the date

of a past illness can be estimated. The nail of digit III consistently grows fastest, that of digit V, slowest. Nails grow rapidly in "nail biters"; in immobilised limbs they grow slowly (Le Gros Clark and Buxton.)

The Hairs are distributed over the entire surface of the body except the palms and soles, dorsum of the last segment of the digits of the hand and foot, red of the lips, parts of the external genitals and the conjunctiva. They are also present in the vestibule of the nasal cavity and in the outer part of the external auditory meatus.

Hairs may be short (a few mm.) or long. Long hairs are present in the scalp, eyebrows, margins of the eyelids, vestibule of the nose, outer part of the external auditory meatus; and at puberty they appear on the pubes, external genitals, axillae, and in the male on the face.

A hair has a *shaft* or part that projects beyond the skin surface, a *root* that lies in a follicle of the skin, and at the end of the root there is a swelling, the *bulb*, which is moulded over a dermal papilla.

Hair rudiments appear about the 3rd foetal month as solid downgrowths of the germinative layer into the dermis. The advancing end swells, is invaginated, and, like an inverted cup, encloses a dermal papilla, in time it may advance into the subcutaneous fat. The polyhedral cells covering the papilla then grow outwards to the surface, becoming more and more elongated as they do so, and reaching it about the 7th foetal month. These hairs, *lanugo*, are shed about the time of birth. Thereafter, fresh hairs are continuously formed by outgrowths from the walls of the hair follicle. The life of a hair on the head is about 2–4 years; of an eyelash about 3 to 5 months; so, like the leaves of an evergreen tree, old hairs are constantly falling out and new ones taking their place.

The cells of the root bulb are polygonal, germinative cells. As these grow out towards the shaft, they become progressively more elongated, cornified and fibrous, and constitute the *cortex* of the hair. Around the cortex is a tube of scaly cells, the *cuticle*, imbricated like the slates or shingles on a roof, the free ends facing the mouth of the follicle and engaging the ends of a similar lining in the follicle but facing in the opposite direction. In some hairs germinative cells extend within the cortex to form a *medulla*.

The Arrectores Pilorum Muscles are bundles of smooth muscle that pass obliquely from the epidermis to the slanting surface of the hair follicles deep to the sebaceous glands. By contracting they cause the hairs to stand erect. In birds, by erecting the feathers, they increase the air spaces between them thereby preserving heat; hence sparrows look plump in cold weather. In man erection of hairs, caused by cold, results in spasms of the Arrectores, producing "goose skin".

Sebaceous Glands are simple alveolar glands, bottle-shaped and filled with polyhedral cells which discharge a fatty secretion, called sebum, into the hair follicles. The glands develop as outgrowths of hair follicles into the dermis, one or more being associated with each hair. Commonly the glands are largest where the hairs are shortest (e.g. end of nose, and outer part of the external auditory meatus.) They make the skin waterproof—"like water off a duck's back" is a common expression. Fortunately there are no hairs on the palms and soles, neither are there sebaceous glands to make the surfaces greasy. Independently of hairs, sebaceous glands

are present on the inner surface of the prepuce, on the labia minora, and on the areolae of the mammae. The tarsal (Meibomian) glands also are modified sebaceous glands.

Boils (and carbuncles) start in hair follicles and sebaceous glands and are therefore possible, indeed common, in the vestibule of the nose and outer part of the external auditory meatus.

Sweat Glands are present in the skin of all parts of the body (red of the lips and glans penis excepted). They are simple tubular glands. The secretory part is coiled to form a ball (0.3 to 0.4 mm. in diameter) situated in the fat of the deepest part of the dermis. The duct runs tortuously through the dermis, enters the epidermis between two papillae, and proceeds spirally to the skin surface. In the stratum corneum it is represented merely by a cleft between the cells. The resemblance to the "intestines of a fairy" was fancifully suggested by Oliver Wendell Holmes. The ceruminous glands in the outer parts of the external auditory meatus and the glands of Moll on the margins of the eyelids are modified "disintegrating" sweat glands. In the axilla, about the external genitals, and around the anus are long, large (3 to 5 mm. in diameter) "disintegrating" sweat glands that produce an odour. They are spoken of as "sexual skin glands".

Sweating lowers the temperature. In man at rest, sweating is observed to begin abruptly when the body temperature is elevated as much as 0.2 to 0.5°F. This is due to the action of the heated blood on the brain centres; and therefore does not occur in the distribution of a peripheral nerve that is severed. Nervousness and fear cause a profuse emotional sweating on the forehead, palms and soles and is associated with pallor. It is odd that, though sweat glands are supplied by sympathetic fibres, adrenalin has no effect upon sweating, and that pilocarpine promotes sweating and atropine diminishes it.

Sweat glands are excretory organs—accessory to the kidneys. The salt taste of sweat is due to sodium chloride. The normal sweat secretion is important in keeping the thick horny layers of the palms and soles supple, and it increases the friction between the skin and an object grasped. In dogs, sweat glands are confined to the foot pads; so, being unable to sweat, dogs pant.

Vessels. The vessels for the supply of the skin run in the subcutaneous fatty tissue. From these the dermis receives two arterial plexuses: one is deeply seated near the subcutaneous tissue; the other is in the subpapillary layer. This sends capillary loops into the papillae. The returning blood passes through several layers of thin-walled subpapillary venous plexuses, thence through a deep venous plexus, and so to the subcutaneous veins. Arterio-venous anastomoses, which are sometimes open and sometimes closed, connect some of these arterioles and venules. The arterial plexuses send twigs to the fat, sweat glands, sebaceous glands, hair papillae and hair follicles.

The natural suffused redness of the skin is due mainly to the subpapillary venous plexus. This is demonstrated by pressing a glass slide against the skin while observing with the microscope: pronounced pallor develops at the moment the subpapillary venous plexus collapses and long before the capillaries empty.

The *lymph vessels* of the skin form a plexus at the junction of the dermis and "hypodermis" (i.e., subcutaneous fatty tissue.) This plexus receives blind finger-like vessels (or networks) from the papil-

lac and it drains into lymph vessels that accompany the subcutaneous arteries and veins.

Nerves. The cutaneous nerves have (1) *efferent* autonomic fibres for the supply of: the blood vessels, arrectores pilorum, sweat and sebaceous glands, and (2) *afferent* somatic fibres of general sensation, namely touch, pain, heat, cold, and pressure (*fig. 51*).

As figure 51 indicates, free fibres end between the cells of the germinative layer (and intra-epidermal injections may cause pain), and around the hair follicle and beside it (probably touch fibres); tactile corpuscles occupy occasional papillae (for touch); Pacinian corpuscles lie in the superficial fascia and are plentiful along the sides of the digits (for pressure). The anatomical basis for heat, cold, and pain is not yet determined; there are heat, cold, and pain "spots" which some believe to be fixed spots, but others do not. The nerves to the joints of the fingers and toes travel via the cutaneous nerves.

Superficial Fascia

Superficial fascia or hypodermis is a subcutaneous layer of **Loose Areolar Tissue** which unites the corium of the skin to the underlying deep fascia. It consists of (a) bundles of *white* or *collagenous fibres* which, by branching and uniting with other bundles, form an open webbing, filled with (b) *tissue fluid;* (c) a slender network of *yellow elastic fibres*, and scattered amongst all this lie (d) *connective tissue cells* (*fig. 52*). When areolar tissue is exposed to the air, the tissue fluids rapidly evaporate with consequent drying and shrinking. Fortunately, the addition of an (antiseptic) saline solution will restore to areolar tissue its original fluffy texture, but once other tissues have become dry and shrunken they remain so.

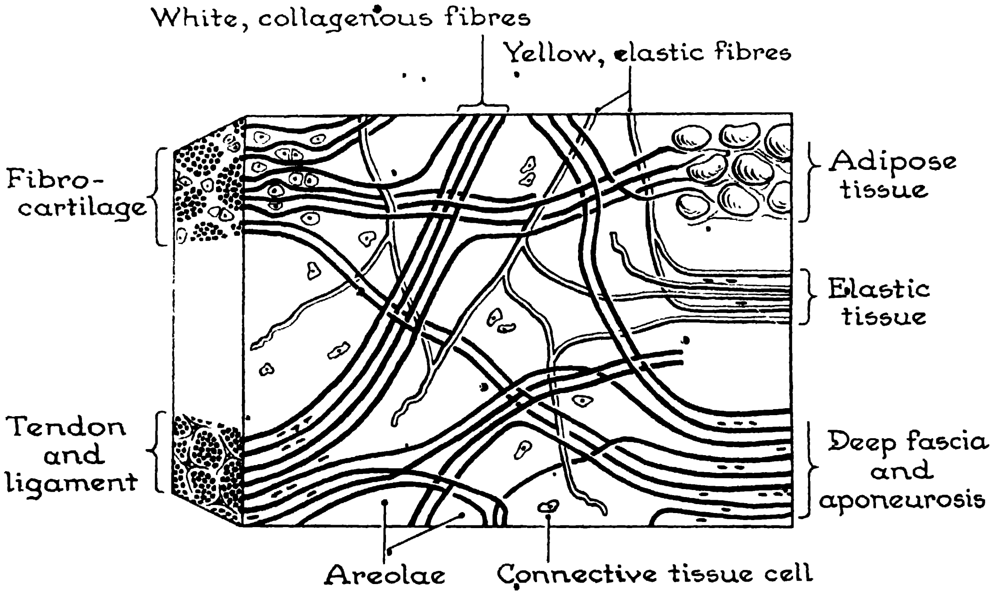


FIG. 52. A diagram of areolar tissue demonstrating that its 4 ingredients when mixed in different proportions form other tissues.

Areolar tissue is derived from those portions of mesoderm that remain after

bones, ligaments, tendons, muscles, and vessels have taken form. It is, therefore, not confined to the subcutaneous fascia but is diffusely spread; for example, it forms the sheaths of muscles, vessels, nerves, and viscera, and it fills up the spaces between them; it forms the basis of the mucous, submucous, and subserous coats of the hollow viscera; the serous membranes (i.e. peritoneum, pleura, pericardium, and tunica vaginalis testis) are but areolar membranes lined with flat mesothelial cells.

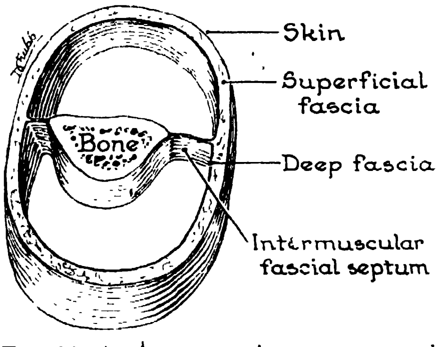


FIG. 53. An intermuscular septum passing from deep fascia to bone.

Areolar tissue is potentially **Adipose Tissue** or fat, and wherever areolar tissue occurs, there fat also may occur. The fat accumulates in the connective tissue cells. Fat is fluid at body temperature but, because each drop of fat is imprisoned in a cell, it does not gravitate to lower levels or flow from a wound. The superficial fascia practically everywhere contains fat except in the eyelids, external ear, penis and scrotum, and at the flexion creases of the digits. In the palms and soles it forms a protective cushion; here and still more so in the breast and scalp it is loculated (*fig. 624*). It is most abundant in the buttocks. In the female fat is most extensively deposited in the gluteal and lumbar regions, front of the thigh, anterior abdominal wall below the navel, mammae, postdeltoid region and cervico-dorsal regions.

Adipose or fatty tissue, as mentioned, is modified areolar tissue, and is notably present in the superficial fascia, the subserous layer of the abdominal wall and the peritoneal omenta and ligaments. It covers parts of the urinary tract (e.g. kidney, ureter, sides of the bladder), but it leaves free the gastro-intestinal tract, liver, spleen, testis, ovary, uterus, and

FIG. 54. Demonstrating the function of a retinaculum (annular ligament). (After Andreas Vesalius—De Humani Corporis Fabrica, 1568 edition: first published in 1543.) (By the courtesy of the Toronto Academy of Medicine.)

lung. It is odd, then, that it should be present in the sulci of the heart. There is no fat within the cranial cavity to dispute possession with the brain, nor within the dura mater covering the spinal cord. The eyeball moves in an oil bath.

Deep Fascia

Deep fascia is the membranous investment of the body deep to the superficial fascia (*figs. 52, 53*). Like tendons, aponeuroses, and ligaments it contains the same four ingredients as areolar tissue, but in different proportions; and, like them, being subjected to tensile strains, the white collagenous fibres form parallel

bundles; the tissue fluids are at a minimum; and the cells are distorted from pressure.

Deep fascia is best marked in the limbs and neck, where it is wrapped around the muscles, vessels, and nerves like a bandage, the fibres being chiefly circularly arranged. Around the thorax and abdomen, which require to expand and contract, there may be a film of areolar tissue but there can be no true deep fascia; nor is there any covering flat muscles (e.g., Trapezius, Pectoralis Major) since there it would have no useful function; nor on the face, since the facial muscles, like the Platysma, are cutaneous muscles.

The deep fascia sends septa, *intermuscular septa*, between various muscles and groups of muscles (*fig. 53*).

Where deep fascia encounters bone, it does not cross it, but attaches itself to it, for the simple reason that both have a common derivation; so, unless some muscle during development intervenes and detaches the fascia from the bone, the two remain attached. At the wrist and ankles there are exceptions to this generalisation.

The deep fascia is thickened where muscles are attached to it, and the direction of its fibres takes the line of pull. It is also thickened about the wrist and ankle to form, as it were, bracelets and anklets, called *retinacula*, which prevent the tendons of muscles from bowstringing (*fig. 54*).

Subcutaneous Bursae are present (a) at the convex surface of joints which undergo acute flexion, because here the skin requires to move very freely, e.g., behind the elbow (olecranon b.), in front of the knee (prepatellar b.) and, sometimes, dorsal to the metacarpo-phalangeal and interphalangeal joints; (b) over bony and ligamentous points subjected to considerable pressure and friction; of these, some are constantly present, e.g., under the heel (subcalcanean b.); others, being acquired or occupational, are inconstant, e.g., those lying superficial to: acromion, ischial tuberosity, lig. patellae, tubercle of the tibia, malleoli, insertion of the tendo calcaneus, and head of the first metatarsal (medial side).

SECTION II

THE UPPER LIMB

CHAPTER 3

INTRODUCTION

Man is a mammal of the Primate Order. He is a biped and he walks erect. His upper limbs are free and are adapted to purposes of prehension and not of locomotion like the forelimbs of the quadruped. They articulate with the trunk at one small joint, the *sterno-clavicular joint*, of their respective sides. They possess great range of movement. His lower limbs have no such freedom. They have to bear the weight of his body when he walks, runs, jumps, and stands. Accordingly, they are united behind to the vertebral column at the sacro-iliac joints, and in front to each other at the symphysis pubis. The security the lower limbs enjoy is in the upper limbs sacrificed to mobility.

The bones of the upper limb are serially homologous with those of the lower limb. The corresponding parts are shown in table 1.

The clavicle or collar bone develops in the membranous tissues deep to the skin and has a different morphological history from the pubic bone which develops in cartilage. Strictly speaking the clavicle is not represented in the lower limb, nor is the pubic bone in the upper limb. They have, however, somewhat analagous functions to perform.

Although it is generally held that the upper and lower limbs are *serially* homologous, the thumb corresponding to the big toe, the radius to the tibia, and the ulna to the fibula, another view has been advanced, namely that the upper and lower limbs are *symmetrically* homologous. This means that just as the two sides of the body are symmetrical, the upper limbs being mirror images of each other, and the lower limbs of each other, so the two ends of the body are symmetrical (biterminal) in so far as the limbs are concerned, the upper limb being a mirror image of the lower limb; the olecranon corresponding to the patella; the thumb to the little toe; the radius to the fibula, etc.

In embryonic life the thumb and the radius, and the big toe and the tibia are situated on the cranial or head side of the central axis of the respective limbs and are said to be pre-axial, whereas the fifth finger and ulna, and the fifth toe and fibula lie on the caudal or tail side of this axis and are said to be post-axial. The palms of the hands face each other, and so do the soles of the feet. Even at birth a baby might clap the soles of its feet almost as readily as the palms of its hands. The upper and lower limbs undergo rotation in opposite directions; the thumb by rotating laterally brings the palm of the hand to the front, whilst the big toe by rotating medially brings the sole of the foot to the ground. The thumb and forearm can voluntarily be caused to rotate medially, as, for example, when you let the palm of the hand rest on the knee. In this position the distal parts of the upper and lower limbs come

to occupy equivalent positions, and it becomes apparent that the dorsum of the hand corresponds to the dorsum of the foot, the back of the forearm to the front of the leg, the elbow to the knee, and the back of the arm to the front of the thigh. The girdles are not involved in this axial rotation.

TABLE 1

UPPER LIMB		LOWER LIMB	
Pectoral girdle	Clavicle Scapula with coracoid process	(Pubis) Ilium Ischium	Pelvic girdle
Arm or Brachium	Humerus	Femur	Thigh
Forearm or Antebrachium	Radius Ulna	Tibia Fibula	Leg
Hand	Carpal bones Metacarpal bones Phalanges 1st or Proximal 2nd or Middle 3rd or Distal	Tarsal bones Metatarsal bones Phalanges 1st or Proximal 2nd or Middle 3rd or Distal	Foot

Mooring Muscles (*fig. 55*). The upper limb is moored to the head, neck and trunk by muscles, which may be likened to guy ropes. The chief are: Trapezius which pulls the limb upwards; the Latissimus Dorsi and Pectoralis Major which pull it downwards; the Serratus Anterior which pulls it forwards; and the Rhomboids which (with the Trapezius) pull it backwards.

Lines of Force Transmission. The following fundamental points should be verified by reference to the skeleton and figure 56.

The clavicle is a strut that thrusts the scapula laterally and backwards. It does so through the medium of a strong ligament, the *coraco-clavicular.* If this ligament holds the scapula (and the rest of the limb with it) away from the median plane, its fibers should pass downwards and medially; and they do. The clavicle has an enlarged medial end which articulates with a shallow socket formed by the sternum and first rib cartilage. A strong *articular disc* prevents the clavicle from being driven medially on to the sternum. This is in virtue of its diagonal mode of attachment to the clavicle above and first rib cartilage below. The lateral end of the clavicle is not enlarged; it does little more than make contact with the acromion, the coraco-clavicular ligament being the es-

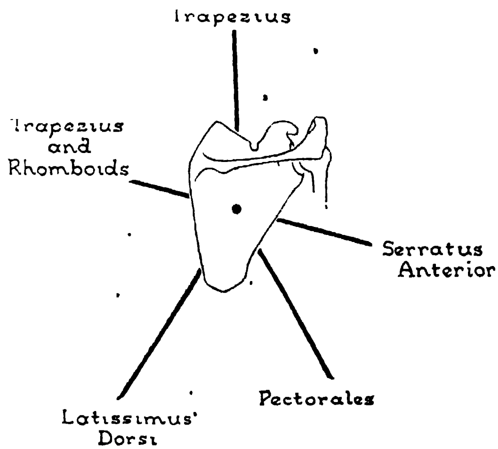


FIG. 55. The upper limb is moored to the body by muscles

sential bond of union between the clavicle and scapula.

At the shoulder joint the rounded head of the humerus makes side to side contact with the shallow glenoid cavity of the scapula. The shoulder joint is more commonly dislocated than any other in the body. The overhanging coraco-acromial arch (i.e., acromion, coraco-acromial ligament, and coracoid process) forms a hood-like roof, which prevents upward dislocation of the humerus. The lower end of the humerus articulates with the ulna and radius.

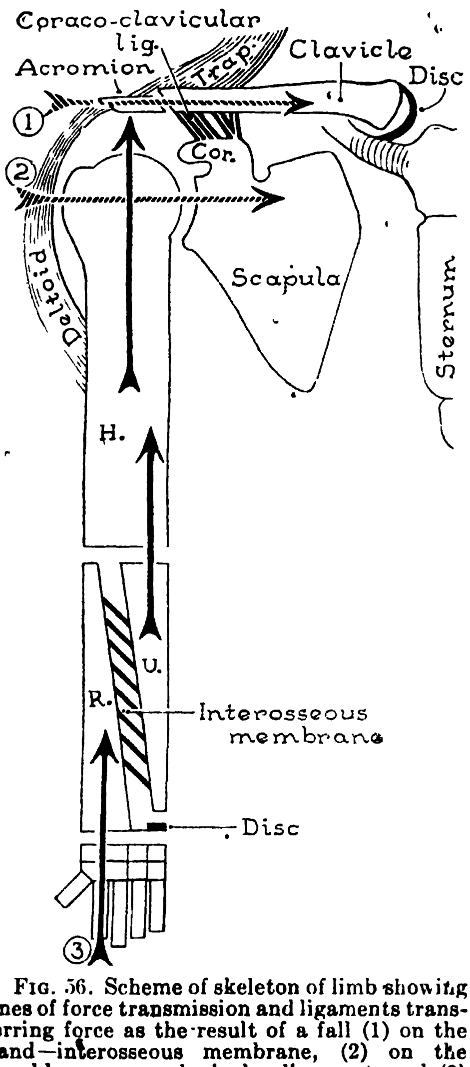


FIG. 56. Scheme of skeleton of limb showing lines of force transmission and ligaments transferring force as the result of a fall (1) on the hand—interosseous membrane, (2) on the shoulder—coraco-clavicular ligament, and (3) on the acromion—articular disc.

The ulna is enlarged above and tapering below; the radius is tapering above and enlarged below; and, the two are united by a strong *interosseous membrane*. Clearly, at the elbow joint the ulna is more important than the radius; at the wrist joint the contrary is true. The enlarged lower end of the radius articulates with two carpal bones, namely, the scaphoid and lunate; but the ulna is separated from the carpal bones by an articular disc that binds the radius to it.

1. An impact, the result of, say, a fall on the palm of the outstretched hand, is transmitted by the scaphoid and lunate bones to the radius; the radius through an interosseous membrane, transfers part of the force to the ulna. To effect this transference of force the fibers of the membrane obviously must pass downwards and medially from radius to ulna. Thence the force travels up the humerus (a) to the overhanging coraco-acromial arch against which the upper end of the humerus abuts and (b) in part across the glenoid cavity to the neck of the scapula, and up the coracoid process. If the force is sufficient to overcome the lower mooring muscles, the acromion and coracoid are driven upwards and the strut (i.e., the clavicle) may snap, because the extent to which it can rise is limited by the costo-clavicular ligament which binds it to the 1st rib cartilage.

2. When force is applied to the side of the upper end of the humerus, the coraco-clavicular ligament prevents the scapula from being driven medially. This it does in virtue of the direction of its fibers.

3. The force of an impact on the acromion is transmitted along the entire length of the clavicle and may result in fracture of the clavicle or in dislocation of the acromio-clavicular joint.

PECTORAL REGION AND AXILLA

The axilla is the pyramidal space above the arm pit. It has four walls, an apex, and a base. *The anterior wall* is fleshy and is formed by the Pectoralis Major and two muscles that lie behind it enclosed in a sheet of fascia, called the *clavipectoral fascia.* This wall is practically synonymous with the Pectoral Region, which, however, includes the medial part of the Pectoralis Major and the breast or mamma superficial to it. *The posterior wall* is formed by the scapula overlaid by the Subscapularis, and below this by the Latissimus Dorsi and Teres Major. When the arm is abducted, the thick fleshy lower borders of the anterior and posterior walls can be grasped between the fingers and the thumb. The anterior and posterior walls diverge medially and converge laterally; so, the medial wall is expansive and the lateral wall restricted *The medial wall* is formed by the upper ribs (2nd to 6th) covered by the Serratus Anterior; it is easily palpated. *The lateral wall* is the bicipital groove of the humerus. It lodges the long tendon of the Biceps, and its lips give attachment to muscles of the anterior and posterior walls. *The base* is the skin and fascia of the arm pit. *The truncated apex* is the triangular space bounded by three bones—the clavicle, the upper border of the scapula, and the first rib. *The contents:* The great vessels and nerves of the upper limb pass through the axilla on their way to the distant parts of the limb. They are the chief contents; the others being lymph glands and fatty tissue, the two heads of the Biceps, and the Coraco-brachialis.

Landmarks. **The Pectoralis Minor** is for your purpose the *central landmark* of this region. To it the axillary vessels and the branches of the brachial plexus bear such definite relationships that, if at any time you become uncertain or confused as to the relation one axillary structure bears to another, it will be to the Pectoralis Minor that you turn in order to get your orientation anew. For this reason it is desirable to have a clear and vivid mental picture of this muscle.

The Pectoralis Minor (*fig. 57*) extends from the (2nd), 3rd, 4th, and 5th ribs, where bone and cartilage join, to the medial border of the coracoid process near its tip. The *tip of the coracoid process* lies one inch below the clavicle under shelter of the anterior edge of the Deltoid. To palpate it in the living subject, you should place your index finger in the gap between the Deltoid and Pectoralis Major, known as the infra-clavicular fossa or *delto-pectoral triangle*, and press firmly not backwards, but laterally under the Deltoid's edge.

In locating the origin of the Pectoralis Minor from the 3rd, 4th, and 5th ribs, remember that the only certain way of identifying any rib lies in reckoning from the *sternal angle* which is at the level of the 2nd costal cartilages. Place therefore your index and middle fingers, one above the other, on the sternum and run them down the middle line of the bone until, about two inches below the suprasternal notch (jugular notch), you encounter the transverse ridge which indicates where the manubrium and body of the sternum articulate with each other. This is the sternal angle. With one finger above the ridge and the other below, follow the ridge laterally to the 2nd costal cartilage. Employing the same two fingers you may

readily palpate the 3rd, 4th, and 5th cartilages through the substance of the Pectoralis Major. Travel along what you estimate to be the length of the 3rd costal cartilage, say two inches, to the costo-chondral junction. By joining this point to the coracoid process you define the upper border of the Pectoralis Minor; similarly by joining the 5th rib near its cartilage, say 4½ inches from the median plane, to the coracoid process you map out the lower border of this triangular muscle.

THE CORACOID PROCESS (Gk. Korax = a crow, i.e., a crow's beak) might more aptly be called the *digital process* (*fig. 58*) because it resembles a finger—a bent finger—in having 3 segments or phalanges, one being vertical and two horizontal, separated by two knuckles and in being flattened at the tip, where the nail might be. (For attachments see *fig 175.*)

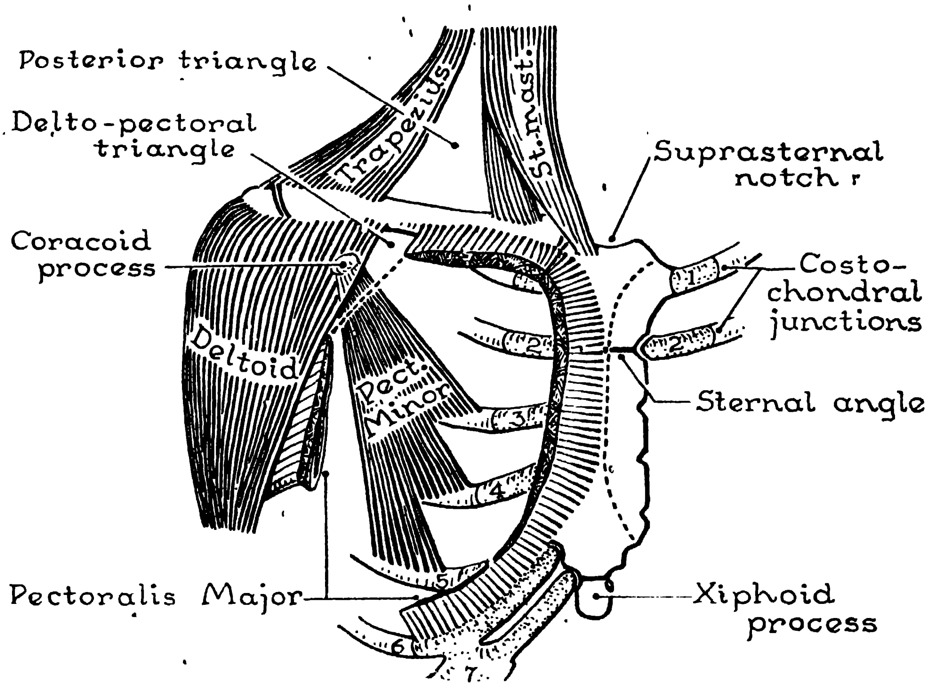


FIG. 57. The Pectoralis Minor—the key to the axilla.

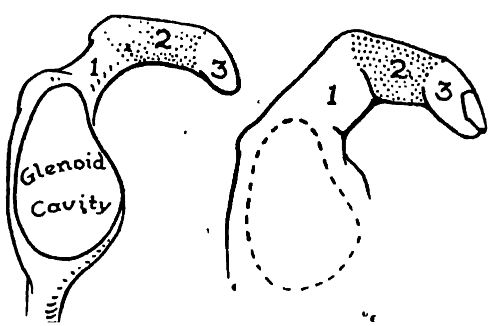


FIG. 58. The coracoid process resembles a bent finger.

The Clavicle, though almost visible through the skin, is not merely subcutaneous but also sub-platysmal, because a thin elastic sheet of muscle, the *Platysma*, descends from the neck to the level of the 2nd or 3rd rib and intervenes between the clavicle and the skin. It is the Platysma that allows the skin to move so freely over the clavicle, and its looseness and elas-

ticity usually saves a fractured clavicle from penetrating the skin. The Platysma is superficial even to the cutaneous nerves, the *supraclavicular nerves*, that cross in front of, or sometimes pierce, the clavicle (*fig. 59*) and descend to the level of the second intercostal space (See page 110, *fig. 92*).

The clavicle is thrice unique: (1) among the bones of the body, in being the first to begin to ossify; (2) among the bones of the limbs, in being occasionally pierced by a cutaneous nerve, and (3) in developing, primarily, not from cartilage but from the tissues deep to the skin; for

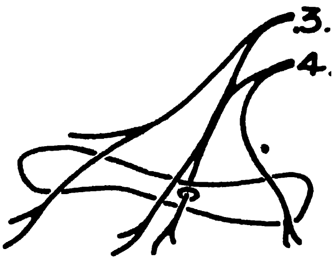


FIG. 59. The supraclavicular nerves sometimes pierce the clavicle.

which reason it is sometimes known as a dermal bone.

You can palpate the clavicle from sternal end to acromial end because a linear strip to which no muscle is attached extends the whole length of its superficial aspect. This strip lies between the attachments of the Sterno-mastoid and Trapezius above and of the Pectoralis Major and Deltoid below.

(The clavicle is described on p. 804.)

Two Triangles. At their attachments to the skull the Sterno-mastoid and Trapezius are continuous with each other, but below they diverge, leaving the middle third of the clavicle free. The triangular space so-formed is the *posterior triangle of the neck.* In the same manner the Pectoralis Major and Deltoid are continuous with each other below at their humeral attachments, but above they diverge slightly (half-an-inch) from each other and form with the clavicle the *delto-pectoral triangle*, which is situated just medial to the coracoid process. The clavicular portions of these two muscles have a common action, namely that of flexing and adducting the shoulder as when raising the arm in boxing, pushing, or lifting the hand to the mouth; and, both derive their nerve supply from the same segments, 5th and 6th cervical. The delto-pectoral triangle allows of the passage of the cephalic vein, its accompanying artery (the deltoid), and lymph vessels.

Walls. From the general description given on page 79, it is evident that one wall is bony; one muscular; two consist of bone overlaid with muscle. The muscles have a blood supply and a nerve supply which are to be regarded as integral parts of the walls. The obvious approach to the axilla is through the fleshy anterior wall and through the fascial base.

THE ANTERIOR WALL. **The Pectoralis Major** has a clavicular and a sternal head of origin (*figs. 57, 61, 63*). The *clavicular head* arises in line with the Deltoid from the anterior aspect of the clavicle below the subcutaneous strip. The *sternal head* meets its fellow of the opposite side along the midline of the body of the sternum; it curves upwards and laterally across the manubrium sterni to the sterno-clavicular joint where it meets the clavicular head; and it curves downwards and laterally along the (5th) or 6th costal cartilage. The two heads have, therefore, a continuous curved fleshy origin from clavicle, joint, sternum, and underlying cartilages. The muscle increases its origin below, not by arising from rib or cartilage, for none is available (the Rectus Abdominis and Obliquus Externus Abdominis having monopolized them),

but by gaining attachment to the External Oblique aponeurosis in front of the Rectus. Again, since the muscle meets its fellow in the median plane, it obviously could not—even if it would—increase its origin medially unless a bony keel were to develop from the sternum, as happens in birds of flight that have need of powerful wing muscles.

The Pectoralis Major is inserted by means of a trilaminar aponeurosis into the lateral lip of the bicipital groove of the humerus. This lip extends upwards from the deltoid tuberosity to the front of the greater tuberosity (*fig. 59*). The clavicular part of the muscle is inserted by means of an anterior lamina, which blends somewhat with the middle lamina behind it. The sternal part is folded upon itself to form a middle and a posterior lamina, continuous with each other below. Thus, the upper sternal fibres pass to the middle lamina; the lower sternal fibres and those from the External Oblique pass to the posterior lamina, and, since the lowest fibres of origin become the highest fibres of insertion, the lower border of the muscle is rolled.

Actions. On considering its attachments it is obvious that all parts of the Pectoralis Major adduct the humerus and rotate it medially. If, whilst palpating your Pectoralis Major, you put the radial side of your closed fist under the edge of a heavy table and try to raise it, you will find that the clavicular part of the muscle comes into action. If, now, you put the ulnar side of your closed fist on the table and press downwards, you will find that the sternal part comes into action. This indicates that the clavicular part aids in flexing the shoulder joint (i.e., brings the humerus forwards) and that the sternal part aids in extending the joint (i.e., brings the humerus backwards).

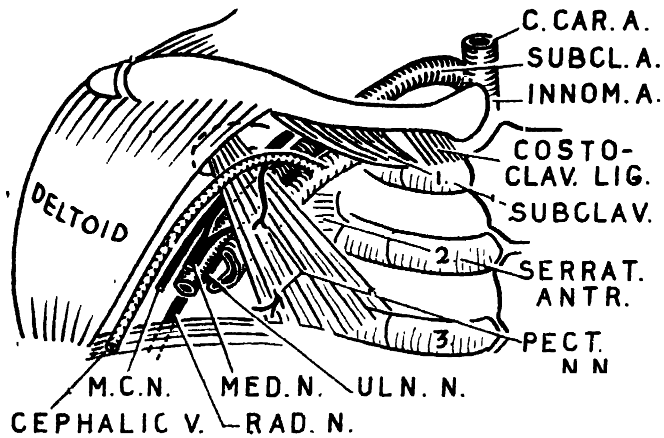


FIG. 60. The upper half of the Pectoralis Major has been removed to show the cephalic vein.

The Cephalic Vein. If the clavicular head of the Pectoralis Major be cut through half-an-inch below the clavicle and parallel to it and thrown down, the cephalic vein (*fig. 60*), which lies in the furrow between the Deltoid and the Pectoralis Major, may be followed through the delto-pectoral triangle, across the anterior aspect of the Pectoralis Minor, and through the costo-coracoid membrane to its termination in the axillary vein. In following it, care need be taken of one structure only, the *nerve to the clavicular*

head of the Pectoralis Major, for this nerve crosses either superficially or deep to the cephalic vein. When crossing superficially it is apt to be injured.

The significance attached to the cephalic vein is two fold: (1) it is the largest vein in the limb, still open, when the more distal parts of the axillary vein are ligated or obstructed by other means; and (2) it serves as a useful guide to the first part of the axillary artery, for the following reason: the axillary artery is overlapped and almost concealed by the axillary vein; so, if the cephalic vein is followed to the axillary vein, and the axillary vein is then displaced infero-medially, the artery will be exposed. If, however, the arm is fully abducted, it may not be possible to displace the vein until either (a) the elbow is raised from the table (i.e., shoulder partially flexed) or (b) the arm is brought towards the side (i.e., shoulder adducted), for both movements relax the vessels and the nerves.

The Costo-coracoid Membrane. This membrane is so-called because it extends from the 1st and 2nd costal cartilages medially to the coracoid process laterally. It is part of a larger fascial sheet, the *clavi-pectoral fascia (fig. 61)*, which extends vertically from the clavicle above to the dome of the axillary fascia below. It acts as a suspensory ligament for the axillary fascia, maintaining its dome-like form. This clavi-pectoral fascia splits below to form a sheath for the Pectoralis Minor, and above to form a sheath for the Subclavius; it is to the portion between these two muscles that the term *costo-coracoid membrane* is given. This fascia is responsible for the sharp lines (anterior and posterior borders of the clavicle) that bound the subclavian fossa on the under surface of the clavicle.

These three—the Subclavius, the costo-coracoid membrane, and the Pectoralis Minor—occupy the same plane and with the Pectoralis Major, which lies in front of them and entirely conceals them, constitute the *anterior wall of the axilla.*

THE POSTERIOR WALL OF THE AXILLA is formed from above downwards by the Subscapularis, Teres Major, and Latissimus Dorsi; the scapula being the background (*fig. 62*). These three muscles are attached to the humerus by tendons and, therefore, to bony elevations; the Subscapularis to the lesser tuberosity, the Teres Major and Latissimus Dorsi[1]

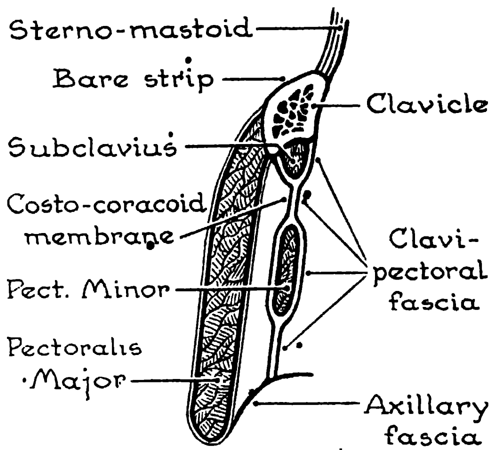


FIG. 61. The anterior wall of axilla (in sagittal section).

to the medial lip of the bicipital groove (intertubercular sulcus) that descends from the lesser tuberosity. Near its insertion the flattened tendon of the Latissimus Dorsi winds below the Teres Major and comes to lie in front of it. Though the Latissimus Dorsi forms the greater part of the lower border of the posterior wall of the axilla, it is the Teres Major that forms the most lateral part of this lower border because its insertion extends slightly below that of the Latissimus. During a dissection, the

[1] Actually the tendon of the Latissimus is inserted into the floor of the groove.

lower border of the Latissimus (but not of the Teres) should be defined and cleaned early because it forms an important side of the "picture frame" of this region; and the nerve and companion vessels of this large and important muscle should be identified, because they are in danger. They enter the deep surface of the muscle half-an-inch from its border at the mid point between the chest wall and the abducted humerus.

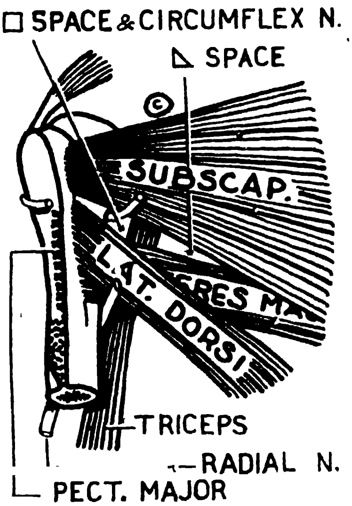


FIG. 62. The posterior wall of axilla

If the Subscapularis be separated from the Teres Major, a long triangular space, whose third side or base is the surgical neck of the humerus, will be opened up. In its depths the long head of the Triceps Brachii will be seen. This head of the Triceps subdivides this long triangular space into a small, unimportant, medial *triangular space* and an important, lateral *quadrangular space* (page 103).

LATERAL WALL OF THE AXILLA. Since the 3 muscles of the posterior wall of the axilla are attached to the lesser tuberosity of the humerus and to the medial lip of the bicipital groove (*fig. 63*), and since the Pectoralis Major of the anterior wall is attached to the lateral lip of this groove, it follows that the lateral wall of the axilla is the narrow interval between these two lips. It is called the *bicipital groove* because it lodges the tendon of the long head of the Biceps.

THE MEDIAL WALL OF THE AXILLA is formed by the ribs and intercostal muscles covered with Serratus Anterior. *The Nerve to the Serratus* (the long thoracic nerve) is one of paramount importance. It must not be damaged, for the Serratus is the chief muscle to protract or pull forwards the scapula, as when pushing (*fig. 64*). If it is paralyzed, attempts to raise the arm in front of the body largely result in causing the inferior angle of the scapula to project from the back. The nerve is to be found running vertically a little behind the mid-axillary line. It is directly applied to the Serratus Anterior and in its course it gives off twigs to it.

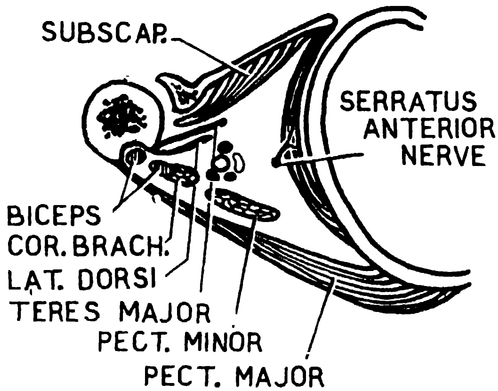


FIG. 63. The axilla on transverse section, showing the 4 walls and the contents.

Vessels. The great vessels and nerves are enveloped in a thin tube, the *axillary sheath*, derived from the fascia covering the Scalene muscles (*fig. 629*). In passing from the neck to the axilla they traverse a triangular space whose patency is maintained by 3 bones—the clavicle,

the first rib, and the upper border of the scapula. As they descend through the axilla they pass from its medial to its lateral wall.

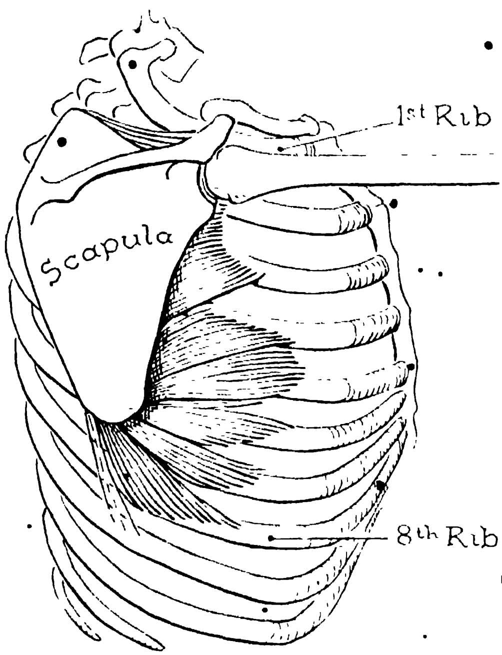


FIG. 64 The Serratus Anterior

The Great Arterial Stem of the limb is referred to as the *subclavian artery* until it reaches the lower border of the first rib. From there to the lower border of the Teres Major it lies within the axilla and is known as the *axillary artery*. On leaving the axilla to enter the upper arm or brachium it becomes the *brachial artery*.

The Pectoralis Minor conveniently divides the axillary artery into three parts, 1st, 2nd, and 3rd (*fig. 65*). Of these, the 1st part traverses a fatty space; the 2nd lies close behind the Pectoralis Minor a finger's breadth from the tip of the coracoid process; the 3rd and longest part crosses the three posterior muscles of the axilla near their insertions.

On voluntarily forcing your arm backwards and downwards you compress the artery between the first rib and the clavicle and so arrest or diminish the radial pulse at the wrist—a trick known to old soldiers—or rather, the clavicle forces the Subclavius, which is inserted into its inferior surface, against the artery. In fact, in the event of the clavicle being fractured the Subclavius serves as a buffer to protect the great vessels and nerves from the ragged ends of the bone. This is the main advantage that accrues from possessing this rather insignificant muscle.

The relations of the artery to the nerves are considered on page 88.

Branches. Branches arise from the 3 parts of the artery, as follows:

1 from the 1st—superior thoracic.

2 from the 2nd { acromio-thoracic, lateral thoracic.

3 from the 3rd— { subscapular, posterior humeral circumflex, anterior humeral circumflex.

The first 3 branches are distributed mainly to the anterior wall and adjacent part of the medial wall; the last 3 to the posterior wall and adjacent parts of the medial and lateral walls.

The superior thoracic a. helps to supply the upper two intercostal spaces.

The acromio-thoracic a. arises at the upper border of the Pectoralis Minor, pierces the costo-coracoid membrane, and divides into four branches which radiate in the plane between the clavipectoral fascia and the Pectoralis Major. Its main duty is, of course, to supply the Pectoral Muscles; accordingly a large pectoral branch descends between the Major and Minor and supplies them. A deltoid branch accompanies the cephalic vein; an acromial branch anastomoses on the upper surface of the acromion, and, a clavicular twig runs to the sternoclavicular joint.

The lateral thoracic a. arises at the lower border of the Pectoralis Minor, and follows it to the chest wall.

The 3 branches of the 3rd part of the axillary artery arises singly or together about the level of the surgical neck of the humerus, that is, between the lower border of the Subscapularis and the upper border of the Teres Major; or, because these structures form three sides of the quadrangular space, the three branches may be said to arise in front of the quadrangular space (*fig. 62*). Emboli or blood clots expelled from the heart during life are apt to lodge at this site, because beyond it the diameter of the main vessel is much reduced in caliber.

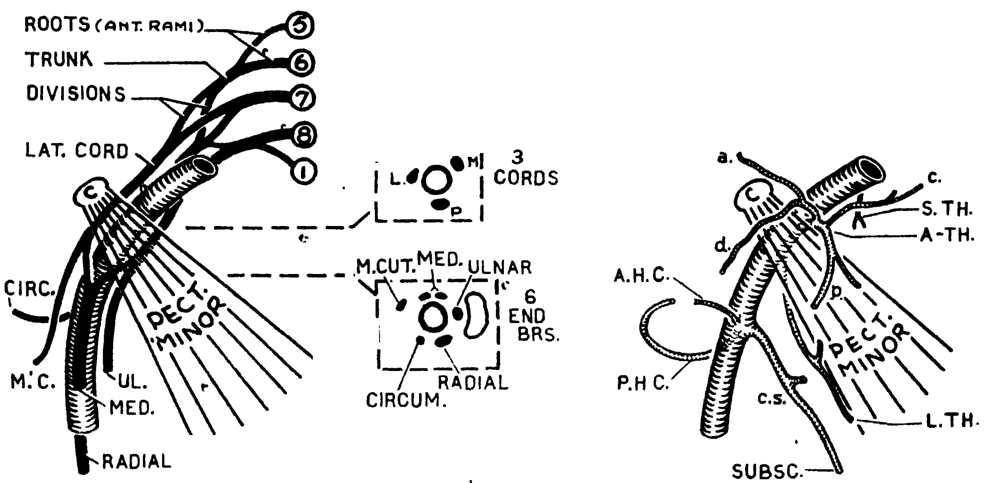


FIG. 65. The brachial plexus and the three parts of the axillary artery.

The subscapular a. is the artery of the posterior wall, and it follows the lower border of the Subscapularis to the medial wall. It sends a large branch, the *circumflex scapular a.*, to the dorsum of the scapula by way of the triangular space. Its other branches accompany 5 important motor nerves (*fig. 66*): the 1st—assuming the *posterior humeral circumflex a.* to spring from its root, which it commonly does—passes through the quadrangular space with the circumflex (axillary) nerve; the 2nd joins the nerves to the Subscapularis; the 3rd follows the nerve to the Teres Major; the 4th follows the nerve to the Latissimus Dorsi; and the 5th or terminal branches end on the chest wall where they meet the nerve to the Serratus Anterior. [It may be noted that the muscles supplied by these five nerves belong developmentally to the dorsal or extensor aspect of the limb.] It is through the anastomoses that this, much the largest of all the branches of the axillary artery, makes on the chest wall, around the scapula, and about the shoulder region, that the circulation in the limb is maintained after the 1st or 2nd part of the axillary artery has been ligated (*fig. 75*). The circumflex humeral arteries encircle the surgical neck of the humerus. *The anterior humeral circumflex a.* is but a twig that spreads out in the bicipital groove.

THE AXILLARY VEIN lies on the medial or concave side of its artery, but it overlaps and conceals the artery when the arm is abducted. It begins at the lower border of the Teres Major as the con-

tinuation of the basilic vein, and it ends at the lower border of the first rib as the *subclavian vein.*

Tributaries. In addition to receiving tributaries corresponding to the six branches of the axillary artery, it receives the two *venae comitantes* of the brachial artery and the *cephalic vein.* It has two or three biscupid valves.

The Brachial Plexus is formed by the alternate union and bifurcation of nerves, thus: 5 anterior nerve *rami* unite to form 3 *trunks,* which bifurcate to form 6 *divisions,* which unite to form 3 *cords,* which bifurcate to form 6 *terminal branches* (*fig. 65*). Of these 6 terminal branches, two soon unite to form the median nerve; hence, the plexus may be said to begin as 5 anterior rami and to end as 5 nerves.

The brachial plexus is constituted as follows: The anterior rami of the 5th and 6th cervical nerves unite; the 7th cervical remains single; the 8th cervical and 1st thoracic unite. Each of the three trunks so-formed divides into an anterior and a posterior division. The three posterior divisions unite together to form a single posterior cord. Of the three anterior divisions, the lateral and intermediate unite to form the lateral cord, while the medial continues its course as the medial cord. Each of the three cords gives off one or more *collateral branches* and ends by dividing into two *terminal branches* (as shown in table 2), the lateral cord dividing into the musculo-cutaneous nerve and the lateral root of the median nerve; the medial cord into the ulnar nerve and the medial root of the median nerve; and the posterior cord into the radial and circumflex (axillary) nerves.

From a glance at figure 65 it should be clear that the musculo-cutaneous nerve and the lateral root of the median nerve can derive fibers from the 5th, 6th, and 7th nerve segments; the ulnar nerve and medial root of the median nerve from the 8th and 1st; the median nerve itself and the posterior cord from each of the five segments.[2]

The medial and lateral cords might better have been called the "antero-medial" and "antero-lateral" cords in order to emphasize the fact that they supply all the muscles on the morphological anterior aspect of the limb and that

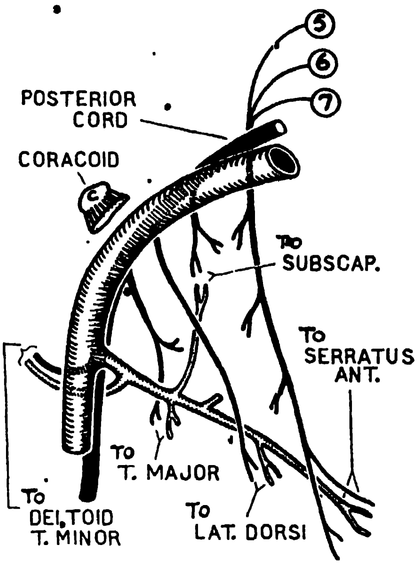


FIG. 66. Branches of the subscapular artery accompanying five motor nerves.

they supply no other muscles. The posterior cord is well named because it is destined to supply all the muscles on the morphological posterior aspect of the limb from the axilla distally, and it supplies no other muscles. As to this fundamental fact you should be perfectly clear.

The anterior rami and the trunks of the plexus occur in the neck; the divi-

[2] In point of fact their origins are: musculo-cutaneous 5, 6, 7; ulnar (7) 8, 1; median (5) 6, 7, 8, 1; radial 5, 6, 7, 8 (1); circumflex 5, 6.

sions behind the clavicle; the cords above and behind the Pectoralis Minor; and the terminal branches distal to it.

RELATION OF PLEXUS TO ARTERY. These various parts of the plexus have now to be related to the axillary artery. Consider, the plexus emerges from the cervical portion of the vertebral column; the great artery arises almost directly from the heart Clearly, then, the plexus cross the artery. The posterior cord takes origin behind and remains behind.

The 2nd part of the artery may be said to perforate the brachial plexus, because the medial cord crossed behind the 1st part of the artery and the two roots of the median nerve unite in front of the 3rd part.

IDENTIFICATION. The medial and lateral cords and their terminal branches

TABLE 2

Derivatives of the Brachial Plexus within the limits of the Axilla

CORDS	TERMINAL BRANCHES	COLLATERAL BRANCHES	
	Mixed (motor and sensory)	Motor	Sensory
Lateral	1. Musculo-cutaneous 2 Lateral root of median	1 Clavicular head of Pectoralis Major (and upper part of sternocostal head)	
Medial	1. Medial root of median 2. Ulnar	1 Sterno-costal head of Pect Major 2 Pectoralis Minor	1 Med cutan n. of arm 2 Med cutan n. of forearm
Posterior	1 Circumflex (axillary) 2 Radial (musculo-spiral)	1. Subscapularis 2 Latissimus Dorsi 3 Teres Major	
From the musculo cutaneous		1 Coraco-brachialis	
From the radial		1 Triceps (long head) and Post cutan n of arm	
From the 5, 6 and 7 roots of the plexus		1 Serratus Anterior	

should at first be above, behind, and lateral to the artery, and it i Observe that the three cords chance to be disposed around the second part of the axillary artery—the part behind the Pectoralis Minor—as their names suggest; that is to say, the posterior cord lies posteriorly; the lateral cord laterally: and the medial cord medially. Obviously, it can only be by crossing the first part of the artery that the medial cord can come to take up a position on the medial side of the second part of the artery; and the crossing takes place behind the artery. It is equally obvious that the lateral cord has no occasion to have the form of a capital "M". This fact should be utilized in identifying them Thus: pick up at random any large nerve below the level of the Pectoralis Minor; place a finger behind it; and run the finger upwards till the cord of which it is a terminal branch is reached; then proceed to follow downwards the other terminal branch of that cord. If for example, you happen to pick up the ***median nerve***, your finger will be conducted by the medial root to the ulnar nerve and by the lateral root to the ***musculo-cutaneous nerve***, which may then be followed downwards. Similarly, if you happen to pick up the ***ulnar nerve***

it will lead to the medial root of the median nerve and so to the median nerve itself. So, by running the finger up and down behind the limbs of the M all three nerves, as well as the lateral and medial cords from which they arise, can be picked up and identified. The collateral branches also can be found. The largest of the collateral branches is the *medial cutaneous nerve of the forearm.* It and the much smaller *medial cutaneous nerve of the arm* arise from the medial cord just before it bifurcates into the ulnar nerve and medial root of the median nerve. If these derivatives of the lateral and medial cords are held aside, the only remaining large nerve, namely, the *radial nerve,* will be identified by this process of exclusion. Unless the foregoing procedure is followed, that is to say, unless the musculo-cutaneous, median, and ulnar nerves are first identified and held aside, the radial nerve may easily be mistaken for the ulnar nerve.

The ulnar nerve always crosses in front of the subscapular artery, but the radial nerve commonly crosses behind it (*fig. 67*).

The identity of the *radial nerve* should be confirmed by following it proximally to the lower border of the Subscapularis, where it and the *circumflex nerve* will be seen to be the two terminal branches of the posterior cord. All three lie behind the axillary artery.

Of the five terminal nerves of the plexus, the circumflex nerve alone does not run longitudinally, but disappears into the quadrangular space. And, it is difficult to find access to it unless the arm can be brought well forwards, that is to say, raised from the table, as by putting a block under the elbow. This simple act renders all the structures on the posterior wall accessible; and adducting the arm renders the great vessels and nerves lax.

Ample exposure is necessary if the terminal branches of the plexus are to be identified with any degree of assurance.

Nerves to the Muscles (*fig. 158,* p. 172). Because the *Pectoral Muscles* belong to the anterior wall of the axilla they must be supplied by anterior cords (i.e., lateral and medial cords). The branch from the lateral cord, the *lateral pectoral nerve* (lateral anterior thoracic n.) was discussed with the cephalic vein (*p. 82*). The branch from the medial cord, the *medial pectoral nerve* (medial anterior thoracic n.) pierces the Pectoralis Minor and supplies it and the lower half of the Pectoralis Major.

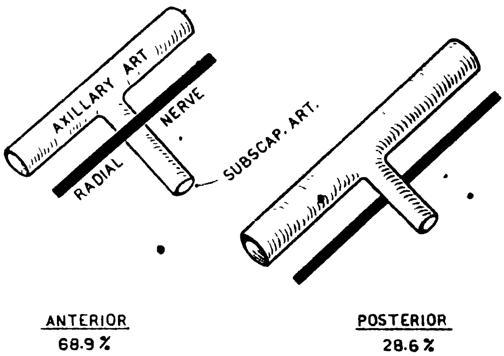


FIG. 67. The relationship of the radial nerve to the subscapular artery is variable. Based on 360 limbs. In 2.5% of cases the subscapular artery was erratic in origin.

Because the *Subscapularis, Teres Major,* and *Latissimus Dorsi* belong to the posterior wall of the axilla, they must be supplied by the posterior cord. Two (or more) branches reach the Subscapularis high up; a third supplies its lower border and passes on to the Teres Major, which it reaches about two inches from the humerus when the arm is abducted. The nerve to the Latissimus Dorsi is readily found on everting the lower border of the Latissimus, for it enters the deep surface of the muscle ½ inch from its border at a point midway between

the chest wall and the humerus when the arm is abducted. Because the nerves to these three muscles arise from the posterior cord and run medially, they must pass behind the axillary vein to reach their respective muscles.

The nerve to the *Serratus Anterior* takes origin in the neck from the roots (5, 6, 7) of the plexus, and because the Serratus is developmentally a posterior muscle, this nerve also passes behind the axillary artery (in its first part) and the axillary vein. It has been remarked already that the nerves to the preceding four muscles and also the circumflex nerve are accompanied by branches of the subscapular artery (*fig. 66*). All of them belong developmentally to the back of the limb.

A combined motor and sensory branch arises from the radial nerve just before it leaves the axilla and while resting on the Latissimus Dorsi or Teres Major: the motor branch supplies the *long head of the Triceps;* the cutaneous branch is the *posterior cutaneous nerve* of the arm

Observe: (a) that the long head of the Biceps is applied to the lateral wall of the axilla, which is synonomous with the bicipital sulcus of the humerus, and, that the insertion of the Pectoralis Major prevents it from being displaced laterally. (b) That the combined tendon of the short head of the Biceps and Coraco-brachialis, which arises from the tip of the coracoid process, also lies close to the lateral wall. (c) That the Subscapularis passes under the arch formed by the coracoid process and conjoint tendon of Biceps and Coraco-brachialis. (d) That the three largest and most important muscular constituents of the walls are the Pectoralis Major, Latissimus Dorsi, and Serratus Anterior—each belongs to a different wall. The nerves to the Latissimus and Serratus are in danger and therefore should be found early in a dissection. (e) That if the finger be swept between the Pectoralis Major and the clavipectoral fascia, the following vessels and nerves will be encountered: medial and lateral pectoral nerves, and the pectoral branches of the acromio-thoracic artery and vein.

The Deep Fascia. Were the chest enveloped in a tough, dense fascia respiration obviously would be interfered with. So, for this reason, if for no other, you might expect the investing fascia in this region to be thin and loosely woven. Later, when you have dissected the anterior abdominal wall and the gluteal region, you will appreciate better the principles underlying the disposition and texture of areolar tissue. The deep fascia here, as over flat muscles in general, is thin and areolar in nature. Where it forms the dome-shaped floor of the axilla it is irregularly laminated. The clavipectoral fascia, which is primarily the sheath of the Pectoralis Minor, acts as a suspensory ligament for the dome-shaped floor of the axilla. You have seen that the great axillary vessels and nerves occupy a tubular sheath, the *axillary sheath* (*fig. 629*), derived from the fascia covering the Scaleni. This sheath is attached to the fascia behind the Subclavius; so, the vessels move with the clavicle. The large quantities of very loose, moist, areolar tissue found between the various muscles of this region are necessary to allow the limb a wide range of movements. No other part of the body enjoys the freedom of movement permitted at the pectoral girdle. These facts concerning the fascia are of considerable practical importance. Fat accumulates especially at the apex of the axilla and on the posterior wall.

A Typical Spinal Nerve is a serially segmental structure which is attached to the spinal cord by *two roots*—an anterior which is motor or efferent, and a posterior which is sensory or afferent. The two roots leave the vertebral canal through an intervertebral foramen and join immediately beyond it to form a *spinal nerve*. Having both motor and sensory fibers the nerve is said to be mixed. After the course of a few mm. the spinal nerve divides into an *anterior* and a *posterior ramus*. Roughly, the posterior ramus supplies the muscles of the back that act on the vertebral column and the skin covering them; the anterior ramus supplies the muscles and skin of the anterior three-quarters of the body wall. There is an enlargement or *ganglion* on the posterior root as it lies in the intervertebral foramen. *Sympathetic ganglia* lie on the sides of the bodies of the vertebrae. Each receives a white fiber (*white ramus communicans*) from the corresponding anterior nerve ramus, and returns one or more gray fibers (*gray rami communicantes*) to the anterior ramus. These gray fibers are distributed to the blood vessels of the body wall and to the glands and muscles of the skin.

The Cutaneous Nerves. The anterior rami of the thoracic nerves are generally called *intercostal nerves*. A typical intercostal nerve gives off a *lateral cutaneous branch* in the mid-axillary line and ends, after piercing the Pectoralis Major at the side of the sternum, as an *anterior cutaneous branch* (*fig. 68*).
The lateral cutaneous branch divides into an anterior and a posterior branch which appear about an inch apart between the digitations of the Serratus Anterior. The anterior branch runs forwards superficial to the Pectoralis Major; the posterior branch runs backwards superficial to the Latissimus Dorsi.

Now, the *first three intercostal nerves* are irregular and interesting. Thus (a) the lateral and anterior cutaneous branches of the 1st intercostal nerve are small or wanting, (b) the lateral branch of the 2nd does not divide into anterior and posterior branches but runs across the dome of axilla in the laminated fascia and then descends on the postero-medial aspect of the arm as the *intercosto-brachial nerve*; (c) the lateral branch of the 3rd sends a branch to the medial side of the arm.

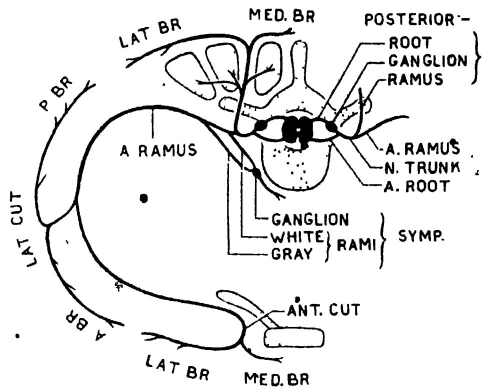


FIG. 68. A typical segmental nerve.

When the upper limb develops, the anterior rami of nerves C. 5, 6, 7, 8 and Th. 1 are drawn out from the trunk to supply the limb. They form the brachial plexus and their simple segmental arrangement is lost. The supraclavicular branches of C. 3 and 4 descend in front of the clavicle to fill the gap or hiatus thus occasioned. In consequence, a person whose 5th cervical vertebra is broken might retain sensation to pinprick as low as the 1st intercostal space. (*Fig. 527.*)

The cutaneous supply to the limb draws upon more segments than the motor supply: for branches from C. 3 and 4 descend to the deltoid region; branches

from Th. 2 and 3 descend to the medial side of the arm. This may be represented thus:

Sensory

Motor

3, 4 5, 6, 7, 8, 1, 2, 3

The Lymph Glands of the Axilla (*fig* 69) are arranged in several main groups: (a) *the lateral glands* lie along the lower parts of the axillary vein. They receive the lymph vessels that ascend along the medial side of the arm and they empty into (b) *the infraclavicular or apical glands* that lie along the upper part of the axillary vein between the Pectoralis Minor and the clavicle. All the vessels of the limb, including those following the cephalic vein, drain either directly or indirectly into this group, and it in turn drains into *the subclavian lymph trunk* which ends in the right lymph duct or (left) thoracic duct. (c) *The anterior or pectoral glands* lie along the lower border of the Pectoralis Minor with the lateral thoracic vein. (d) *The posterior or subscapular glands* lie along the subscapular veins. (e) *The central glands* lie between the layers of fascia at the base of the axilla or in the fat deep to it. (f) Occasionally one or two small glands occur in the *delto-pectoral triangle*.

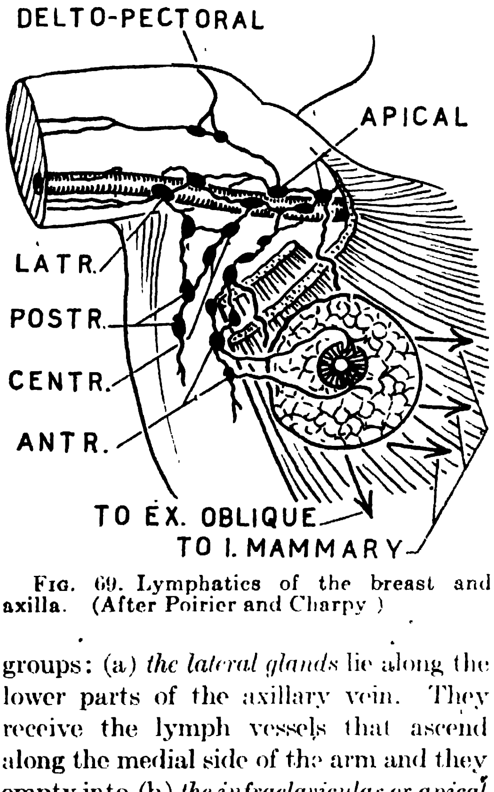


FIG. 69. Lymphatics of the breast and axilla. (After Poirier and Charpy.)

On drawing the fingers downwards across the ribs it is commonly possible to palpate the central group of glands.

The Mammary Gland or breast (*fig. 70*) will likely have to be studied from museum dissections and preparations. It is made up of 15–20 units of glandular tissue, whose lobules, enclosed in a fibro-areolar stroma, radiate from the nipple into the surrounding superficial fat, much as spokes radiate from the hub of a wheel. The periphery of the gland, or rim of the wheel, extends from the 2nd to the 6th rib in the vertical plane and from the side of the sternum to near the midaxillary line in the horizontal plane. Of the several tail-like processes it may possess, one runs upwards along the lower border of the Pectoralis Major to the 3rd rib level. About two-thirds of the gland overlies the Pectoralis Major; one-third the Serratus Anterior. Though easily separated from the fascia covering these muscles, it is firmly connected to the true skin by fibrous bands that proceed from its stroma between lobules of fat. These are the *ligaments of Cooper*.

In the pinkish areola surrounding the nipple there is a number of nodular rudimentary milk glands, called the tubercles of Montgomery; and deep to the areola is some unstriped muscle, a lymph plexus, and an absence of fat.

The 15–20 milk ducts possess slight dilatations, the *lactiferous sinuses*, at the base of the nipple and they open on to its apex.

Vessels and Nerves. *Nerves:* Intercostal nerves (2nd–6th), via lateral and anterior cutaneous branches. These or the vessels convey sympathetic fibers.

Arteries: Perforating branches (especially the 2nd and 3rd) of the *internal mammary a.* and two external mammary branches of the *lateral thoracic a.* approach the gland from the sides, ramify

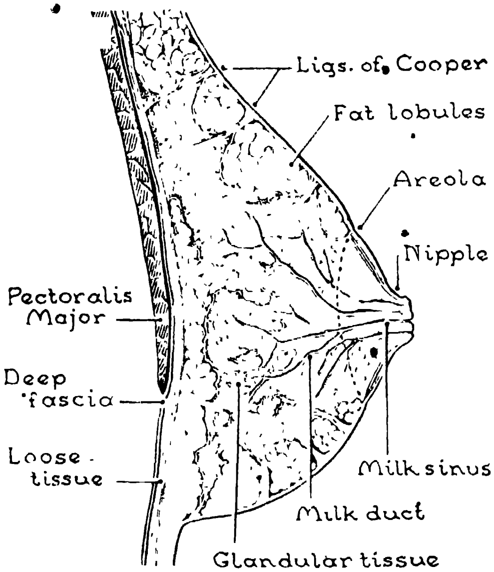


Fig. 70

Fig. 70. The mamma on vertical section. (After Testut.)

on its superficial surface, send branches into it, and anastomose around the nipple. Twigs from the *intercostal aa.* may enter the deep surface of the gland.

Lymphatics: The main lymph vessels, like the ducts of the mamma, converge on the nipple. Deep to the areola they form a subareolar lymph plexus (*fig. 69*). (a) From this plexus two or three distinct vessels course superficially to the upper pectoral lymph glands. (b) From the medial border of the mamma lymph vessels pass to the internal mammary lymph glands, which lie with the internal mammary a. (c) From the deep surface of the mamma lymph vessels pass through the Pectoralis Major to end in the interpectoral glands, which lie superficial to the Pectoralis Minor and costo-coracoid membrane, or passing through these end in the infraclavicular (apical) glands.

Anomalies. In this region you may quite possibly have met with one or more of the following anomalies: *Accessory* or *rudimentary mammae* are occasionally found along the "milk line" between axilla and pubis, or elsewhere (*fig. 71*).

Sternalis muscle: a flat muscle lying in front of the Pectoralis Major and in line with the Sternomastoid and Rectus Abdominis. Its presence is often associated

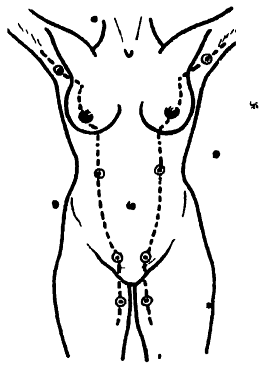


Fig. 71. Accessory nipples may appe the milk line.

with anomalies of the adrenal gland and with a defect of the skull (anencephaly).

Axillary Arch: a band of voluntary muscle, ½″ wide, that stretches across the base of the axilla from the Latissimus Dorsi to the Pectoralis Major or coracoid process. Like the Platysma it is a vestige of the Panniculus Carnosus, so conspicuous in many mammals and it is generally supplied by Th. 1 or 2. Unless aware of this as a possibility you may be disconcerted on meeting it.

Pectoralis Major: its sternal head may be absent.

The ulnar nerve (C. 8 and Th. 1) commonly derives fibers from C. 7 via the lateral cord.

The lateral root of the median nerve (or part of it) may travel with the musculo-cutaneous nerve far into the arm before joining the medial root.

SCAPULAR AND DELTOID REGIONS

Bony Parts. The *spine* of the scapula crosses the medial four-fifths of the *dorsum of the scapula* obliquely dividing it into a smaller *supraspinous* and a larger *infraspinous fossa.* These two fossae communicate with each other at the *spino-glenoid (scapular) notch* which lies between the lateral border of the spine and the *glenoid cavity (fig. 72).* The posterior border or *crest of the spine*—often for the sake of brevity referred to as "the spine"—ends above the shoulder joint in a free, flattened and expanded piece of bone, the *acromion.* The acromion has on its medial border, very close to its tip, a small oval bevelled facet for articulation with the flattened acromial end of the clavicle. The crest of the spine, the acromion, and the clavicle form a continuous bony arch which you can palpate from end to end through the skin. This is possible because no muscle—save the Platysma—crosses any part of this arch.

The *acromio-clavicular joint* surfaces are not weight-bearing and are not enlarged, like the ends of long bones in general. The joint is subcutaneous. You can easily locate it by pressing medially with the finger tips because the acromial end of the clavicle is a little thicker than the acromion and it projects above it.

The *medial* or *vertebral border* of the scapula is covered in its upper half by the Trapezius, but you can easily palpate it from the *inferior angle* to the *superior (medial) angle.* The *lateral or axillary border* you can trace with some difficulty. The inferior angle and the tip of the coracoid are, so to speak, at opposite poles of the scapula. By grasping the inferior angle with one hand and palpating the coracoid process with two fingers of the other, you can so manipulate the scapula that a fracture between the "*two poles*" would reveal itself.

The vertebral border is almost parallel with the spines of the vertebrae and is about two inches distant from them. This border crosses 6 of the 12 ribs and leaves the other 6 uncrossed. And, since the superior angle overlies the second rib and the inferior angle the seventh rib or seventh interspace, it follows that there is one uncovered rib above the superior angle, and that there are five below the inferior angle.

A line dropped vertically from the inferior angle of the scapula is known as the "*scapular line*". The inferior angle forms a valuable practical guide to the upper limits of the diaphragm and liver and to the lower limits of the lung (*p. 259*).

The root of the spine of the scapula lies at the level of the 3rd thoracic spine.

Note that although the eighth rib takes a downward slope, in the scapular line it is on practically the same level as the tip of the spinous process of the eighth thoracic vertebra. This is due to the fact that the spinous process also takes a downward slope.

The scapula is homologous with the ilium; the coracoid process with the ischium; the clavicle is not homologous with the pubis, but to some extent the two are analogous. The ilium articulates with the vertebral column at the sacro-iliac joint; and this union makes for stability of the lower limb. The scapula, on the other hand, does not articulate with the vertebral column, and in consequence the upper limb possesses freedom of movement, but at the expense of stability. The large quantity of loose

spongy areolar tissue, encountered between the flat muscles that attach the upper limb to the head and trunk, is required to allow this freedom.

Cutaneous Nerves. The anterior rami of nerves C, 5, 6, 7, 8 and Th. 1, it will be remembered, take part in the brachial plexus, and send no cutaneous branches to the pectoral region. The posterior rami of these same nerve segments have likewise a restricted distribution: the posterior ramus of the middle nerve of the series, namely the 7th, has no cutaneous branch; of those on either side of it, the 6th sometimes, the 8th generally is absent; while the 5th cervical and 1st thoracic are present, but small. Both, therefore, on the front of the girdle and on the back there is a similar break in the sequence of the cutaneous nerves.

A typical posterior nerve ramus divides into a medial and a lateral branch (*fig. 68*). Both branches supply muscles, and one or other branch becomes cutaneous. Above the mid-thoracic region it is the medial branches that become cutaneous, and they do so close to the median plane; below, the lateral branches become cutaneous at some distance from the median plane. The posterior ramus of Th. 2 extends to the acromion and is therefore the longest of the posterior rami. The strip of skin each cutaneous nerve supplies is below the level at which its nerve ramus emerges from the vertebral column.

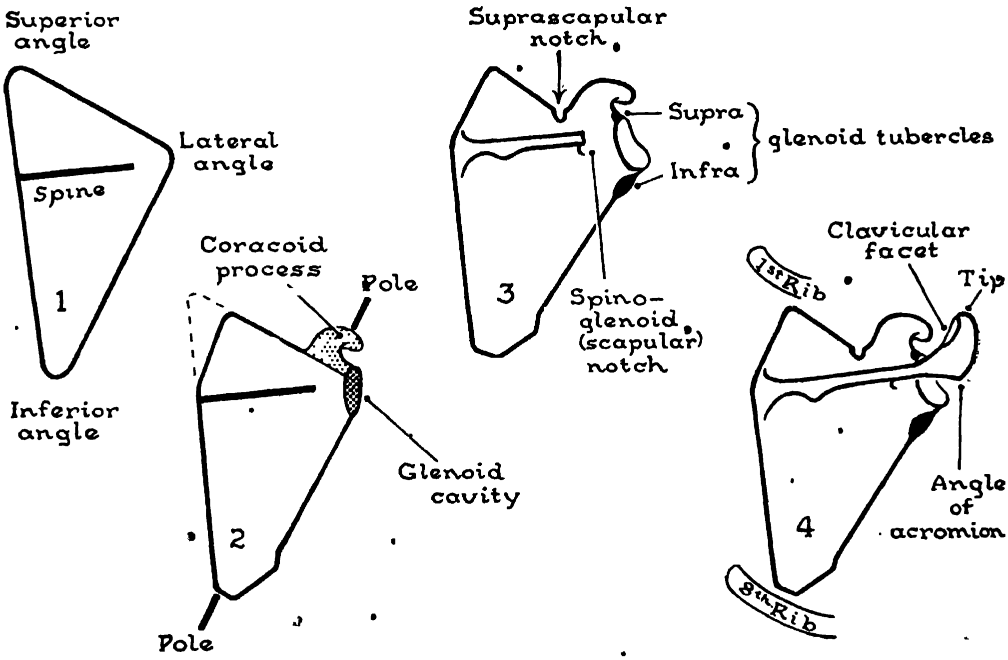


FIG. 72. Progressive stages in sketching a scapula, from behind.

The Latissimus Dorsi. The Subscapularis, Teres Major, and Latissimus Dorsi have differentiated from closely related premuscle masses. The facts (a) that the nerve to the Teres Major supplies a branch to the Subscapularis, (b) that the Teres Major and Latissimus describe complete half turns, and (c) that the Latissimus commonly has a slip of origin from the back of the inferior angle of the

scapula in conjunction with the Teres Major bear evidence of this. During development the Latissimus has evidently migrated further than its two companion muscles, for its origin now extends in a fan-shaped manner from the 7th thoracic spine to the middle of the outer lip of the iliac crest. Between these two points its aponeurotic origin is attached to the

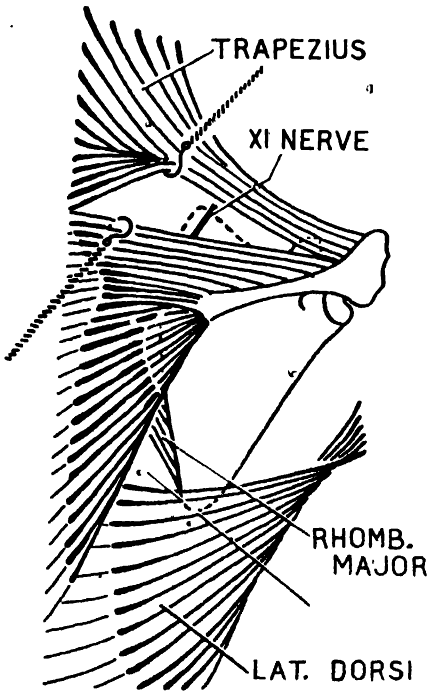


FIG. 73. Exposure of upper border of scapula: Triangle of auscultation.

lower six thoracic, the lumbar, and the sacral spines and to the lateral lip of the iliac crest, largely through the medium of the lumbar fascia. It also arises from the lower 3 ribs by fleshy fibers that interdigitate with the External Oblique of the Abdomen in series with those of the Serratus Anterior.

Actions and Functions. The Latissimus extends the humerus, rotates it medially, and adducts it. It brings the outstretched arm from above the head to behind the back. It is used in swimming, in raising the body when one hangs from a horizontal bar, in rowing, in pulling, in elbowing ones way through a crowd.

Two Triangles. The upper horizontal border of the Latissimus overlies the inferior angle of the scapula, and carried medially reaches the 7th thoracic spine. Between this border of the Latissimus Dorsi, the Trapezius, and the Rhomboid Major there is a triangular area, the *Triangle of Auscultation.* Its floor is the naked thoracic wall. It is formed by the 6th interspace and the ribs bounding it (*fig. 73*).

The anterior oblique border of the Latissimus often fails to meet the posterior border of the Oblique Externus Abdominis at the middle of the iliac crest in which case another triangular area, the *Lumbar Triangle* (of Petit) is formed. Its floor is the Obliquus Internus Abdominis.

The Trapezius is triangular in shape. The Trapezii of the two sides together form a trapeze or table; hence the name. This muscle is attached to the medial third of the superior nuchal line of the occipital bone, to the inion, to the tips of the spines of all the cervical and thoracic vertebrae and to the intervening supraspinous ligaments. The attachment to the cervical spines is not direct but through the medium of the ligamentum nuchae. The upper fibers of the muscle pass infero-laterally to the posterior border and adjacent part of the upper surface of the flattened lateral third of the clavicle; the intermediate fibers pass horizontally laterally to the medial border and adjacent part of the upper surface of the acromion, as well as to the upper lip of the crest of the spine of the scapula; the lower fibers, that is to

say, those arising below the level of the root of the spine of the scapula, converge as they pass supero-laterally and form an aponeurosis which is inserted into and accounts for the well marked tubercle on the lower lip of the crest of the spine. Note the direction of this tubercle.

Functions. The Trapezii are the suspensory muscles of the shoulder girdles. In health they are in tone, holding the shoulders back and up, thus giving a "military carriage". Drooping or bottle-neck shoulders are indicative of Trapezii lacking in tone. The Trapezius comes into play, raising or steadying the shoulder girdle, whenever a weight is either supported on the shoulder or is carried in the hand (*fig. 162*). The lower fibers are not necessarily antagonistic to the upper fibers. In fact, they assist the upper fibers to rotate the scapula, for when the upper fibers raise the point of the shoulder, the lower fibers, by pulling on their tubercle of insertion depress the vertebral border. The middle, horizontal fibers form the thickest part of the muscle; they are used in pulling.

If the muscle is paralyzed the normal concavity of the neck becomes an angularity, the point of the shoulder droops, and extra work is then thrown upon the Serratus Anterior.

Nerve Supply. The Trapezius is supplied on its deep surface by (a) the spinal part of the accessory nerve (motor), which arises from the upper 5 cervical nerve segments and takes a devious course, and (b) by cervical nerves 3 and 4 (sensory) which take a direct course (*K. B. Corbin*) (*fig. 716*). The nerve should be exposed where it crosses the superior angle of the scapula. This is done by separating rather than severing the muscle fibers which here run horizontally. The separation is made with the knife carefully because the nerve adheres to the deep surface of the muscle.

The Key to the Suprascapular Region is the upper border of the scapula. To find this border, continue the separation of the fibers of the Trapezius laterally to the acromion and medially to the vertebral spines. If the subject is stout, short-necked, or very muscular, easier access may be gained by detaching the lower half of the muscle from the vertebral column and turning it laterally.

Note on the skeleton that the *upper border of the scapula* extends from the superior angle, where the Levator Scapulae is inserted, to the upper part of the glenoid cavity where the long head of the Biceps arises from the *supraglenoid tubercle* (*fig. 72*). The medial part of this border is subjected neither to stress nor to strain, and as it affords attachment to only one muscle, the slender Omohyoid, it has no occasion to be other than thin and sharp. Laterally, it becomes abruptly deeper—the *suprascapular notch.* This notch is bridged by a sharp, taut band the *suprascapular (superior transverse) ligament.* Between the notch and the supraglenoid tubercle the border is drawn out into the stout *coracoid process.*

To regard the coracoid process as a projection from the upper border is a most useful practical conception. Morphologically, the coracoid is a separate bone, an "atavistic epiphysis", which is so constant in fusing with the rest of the scapula during the 15th year that it serves as a valuable criterion of the age of a skeleton.

The upper border of the scapula cannot be seen from behind, since being concave it is, of course, concealed by the upper border of the Supraspinatus, which being straight, rises above the concavity. With this in mind, pass the index finger over the upper border of the Supraspina-

tus and down its anterior surface till the sharp concave upper border of the bone is felt. Then, by sense of touch run the finger laterally along the upper border of the bone and of the suprascapular ligament to the root of the coracoid (*fig.* 74). Do this in disregard of the unimportant Omo-hyoid which is attached near the notch. *Thence run the finger up the coraco-clavicular ligament to the clavicle, and then medially behind the posterior surface of the clavicle.*

the spinoglenoid notch to the infraspinous fossa.

The nerve supplies the Spinati and sends twigs to the shoulder joint. It has no cutaneous branches.

The Vertebral Border of the Scapula. When the lower part of the Trapezius is thrown down, the Levator Scapulae and the two Rhomboids are partly exposed. Together they occupy the whole length of the vertebral border of the scapula. The *Rhomboideus Minor* finds attach-

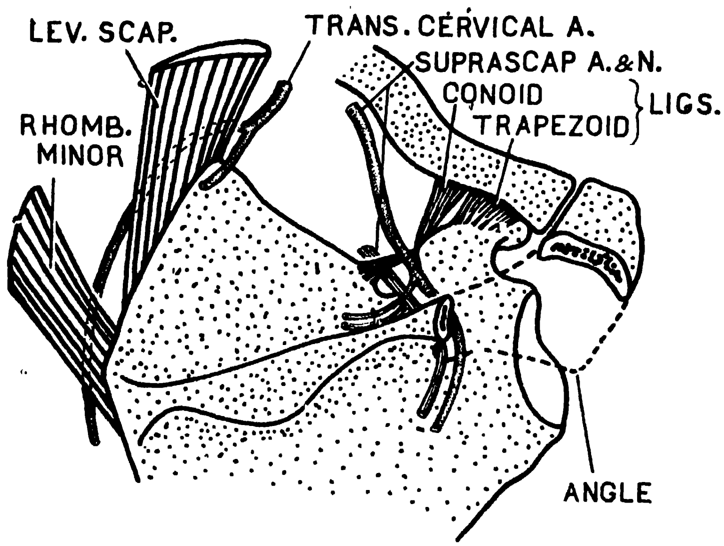


FIG. 74. Upper border of scapula—the key to the suprascapular region.

With the aid of these fixed landmarks you can find your way about; without them you grope.

(The scapula is described on p. 806.)

Suprascapular Vessels and Nerve. With a little blunt dissection the suprascapular (transverse scapular) vessels, crossing above the ligament, will be set free; and the suprascapular nerve, crossing below the ligament, can be picked up with a blunt hook. On the dorsum of the scapula the suprascapular vessels and nerve lie in contact with the bone. They pass from the supraspinous fossa through

ment at the level of the root of the spine; the *Levator Scapulae* is attached to the border above this level; and the *Rhomboideus Major* below it. The fibers of the Levator Scapulae often turn the superior angle; the fibers of the Rhomboideus Major exert their pull on the inferior angle for, as a little care will show, the upper part of the attachment of this muscle is not so much an insertion as an areolar connection.

The origin of the Levator Scapulae from the posterior tubercles of the transverse processes of the upper four cervical

vertebrae is not displayed, neither is the upper part of the origin of the two Rhomboids from the lower part of the ligamentum nuchae and tips of the spines of the last cervical and upper four thoracic vertebrae and corresponding supraspinous ligaments.

THE TRANSVERSE CERVICAL ARTERY passes backwards on the floor of the posterior triangle of the neck till it meets the anterior border of the Levator Scapulae which, as it were, splits it into a superficial (ascending) and a deep (descending) branch. The *superficial branch* accompanies the *accessory nerve* on the deep surface of the Trapezius, while the *deep branch* passes deep to the Levator Scapulae and Rhomboids and runs close to the vertebral border of the scapula in company with the *nerve to the Rhomboids.*

The Anastomoses on and around the scapula are very free. They bring notably the 1st part of the subclavian artery into a communication with the 3rd part of the axillary artery (*fig. 75*). Thus: the transverse cervical and suprascapular arteries, which are branches of the subclavian artery via the thyrocervical trunk, communicate freely on both surfaces of the scapula with branches of the subscapular artery. On the acromion, the acromial branches of the suprascapular, acromio-thoracic, and posterior humeral circumflex arteries bring the 1st part of the subclavian, 2nd part of the axillary, and 3rd part of the axillary arteries together. On the thoracic wall, the intercostal arteries anastomose with the transverse cervical, superior thoracic, lateral thoracic, and subscapular arteries.

If it is proposed to cut through the Rhomboids, let it be done carefully, because their origins share the tips of the vertebral spines with several other muscles and, so, are aponeurotic. Too deep an incision will be found to have divided also the subjacent aponeurosis of the Serratus Posterior Superior. This is in accordance with the *axiom*—when several muscles are crowded on to a limited area of bone, their attachments must be fibrous. The aponeurotic attachments of the adductors of the thigh to the linea aspera of the femur afford comparison.

Serratus Anterior. If now the fingers be passed round the vertebral border of the scapula, they will come into contact

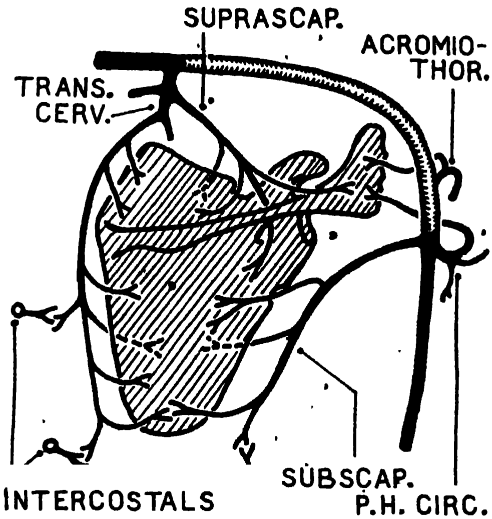


FIG. 75. Scheme of the anastomoses around the scapula.

not with the Subscapularis, as one is tempted to think, but with the Serratus Anterior, which is interposed between the Subscapularis and the chest wall (*fig. 76*).

Though the Serratus Anterior forms the medial wall of the axilla and its nerve was studied with the axilla, the muscle can be examined better now.

The Serratus arises from the outer surfaces of the upper 8 ribs by a series of fleshy digitations: those arising from the upper 4 ribs are hidden by the Pectoralis Minor; those arising from the lower 4 ribs interdigitate with the upper digitations of the Obliquus Externus Abdo-

minis. The Serratus is inserted into the costal aspect of the medial border of the scapula by a linear attachment that enlarges into a small triangular area at the superior angle and into a large triangular area at the inferior angle. Only 3 ribs (1, 2, and 3) send digitations to the superior angle and medial border; while 5 ribs (4, 5, 6, 7, and 8) send converging digitations to the inferior angle. The reason for this distribution is apparent. The fibers are concentrated where they act to best advantage, which is the end of a lever.

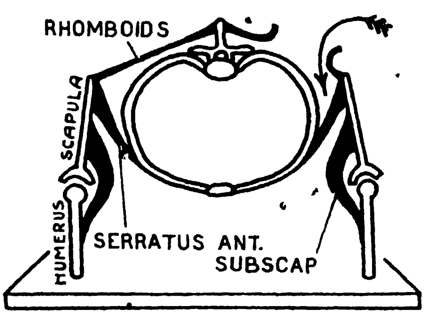


FIG. 76. Demonstrating the antagonistic and complementary uses of the Serratus and Rhomboids.

Functions. The lower digitations are required to steady or pull forwards the inferior angle when the arm is raised in front of the body. The upper digitations draw the scapula forwards, thereby increasing the reach of the outstretched hand.

During the excursions of the scapula, the Rhomboids and the Serratus Anterior together keep the medial border applied to the thoracic wall. If either be paralyzed "a winged scapula" will result; that is to say, the inferior angle will project on the back.

The Acromio-Clavicular Joint. Note that fibers of the Trapezius cross the acromio-clavicular joint in the same direction as the fibers of the capsule, and augment them. With two parallel antero-posterior cuts, open into the joint from above and remove the wedge-shaped disc which projects into it as does a semilunar cartilage into the knee joint. The capsule is about equally thick all round the joint. Note that the small, oval joint surfaces are so set obliquely that if a fall on, or a blow applied to, the edge of the acromion should result in dislocation, the acromion will be driven below the clavicle. The *conoid* and *trapezoid ligaments,* into which the *coraco-clavicular ligament* is subdivided, resist such a force; that is to say, it is their duty to hold the scapula laterally and to prevent it from being driven medially. If this be true, their fibers must obviously pass infero-medially; which they do. In verification of this (a) pull the humerus laterally and note that these two ligaments become slack, (b) push the humerus or the scapula medially and note that they become taut. The conoid ligament is in the form of an inverted cone; it is, however, not balanced on its apex but is so poised that its fibers share in the general infero-medial direction, as do those of the trapezoid ligament. If they are to retain the scapula in position, they could obviously take no other direction.

Bones and Epiphyses. The portion of the *clavicle* medial to the coracoid process (medial two-thirds) has to perform the duties of a long bone; and it would seem that on this account it is triangular on cross section. It may, therefore, be described as having 3 surfaces separated by 3 borders, and an enlarged sternal end which possesses a scale-like epiphysis. The acromial end (lateral one-third) is flattened and has 2 surfaces separated by 2 borders. It usually has no epiphysis.

The acromion is stronger than you

might think, for the lateral border of the spine of the scapula, which bounds the spino-glenoid notch, is very stout and rounded—evidently with the object of buttressing and strengthening the acromion, on the under surface of which it fades away (*fig. 80*).

During the 15th year, when the *coracoid process* is fusing with the scapula along a line that includes the upper part of the glenoid cavity (*fig. 77*), the end of the *acromion* begins to ossify from two

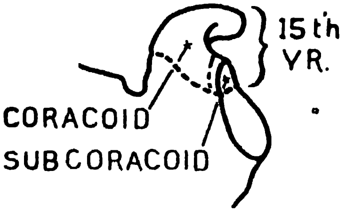


FIG. 77. Coracoid epiphyses.

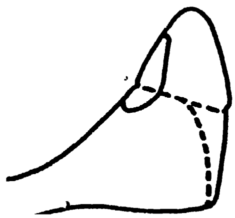


FIG. 78. Acromial epiphyses.

centres—one near the tip, the other near the angle. These fuse with each other and with the acromion after the age of twenty years along a line that passes either through or just behind the facet for the clavicle (*fig. 78*). The epiphysis at the tip commonly fails to fuse and, on X-ray examination, may simulate a fracture. The failure to fuse, is, however, commonly bilateral.

The Humerus. The upper end of the humerus is so much concerned in this region that it must be examined now (*figs. 79, 80*). It consists of: an articular portion, the *head*, which forms a third of a sphere, is covered with cartilage, and is directed medially, upwards, and a little backwards. Surrounding the articular cartilage is the *anatomical neck* to which the fibrous capsule of the joint is attached. A mass of bone, affording attachment to the tendons of four muscles that retain the head in its socket, projects

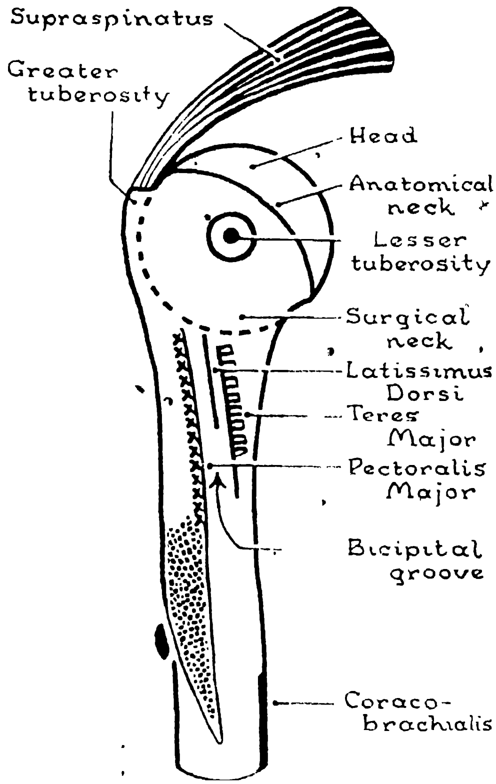


FIG. 79. Upper half of humerus (anterior view, schematic).

both in front and laterally (*fig. 170*). This mass is divided into two unequal parts, the *lesser* and *greater tuberosities*, by a groove, the *bicipital* (*intertubercular*) *sulcus*, wherein lodges the long tendon of the Biceps. The prominent lesser tuberosity lies, so to speak, at the centre of a circle, and is directed straight forward—when the limb is in the anatomical position. On rotating the humerus me-

dially and laterally, it can be palpated through the Deltoid. It is situated $1\frac{1}{2}$ inches infero-lateral to the tip of the coracoid process. It gives attachment to the Subscapularis. The less prominent greater tuberosity projects laterally beyond the acromion and so gives the shoulder its roundness. It too can be

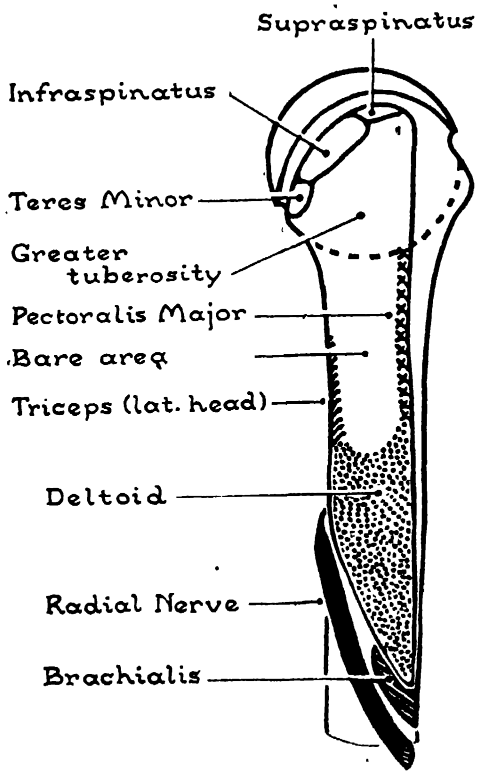


FIG. 80. Upper half humerus (lateral view, schematic).

palpated through the Deltoid. It possesses three flat contiguous facets: a horizontal one above for the Supraspinatus, a vertical one behind for the Teres Minor, and joining these two an oblique one for the Infraspinatus. Its lateral aspect passes imperceptibly into the shaft of the bone below. The tuberosities, then, are separated from each other by the bicipital sulcus; from the head by the anatomical neck; and from the body by the surgical neck.

The *surgical neck*, being a region of practical surgical importance, may be described in a practical way as the narrow zone that is partly encircled by the circumflex (axillary) nerve and completely encircled by the circumflex vessels. In encircling the neck, the nerve and vessels require to pierce no muscle, because they are able to pass between the 4 muscles inserted into the greater and lesser tuberosities above and the 3 muscles inserted into the *medial* and *lateral lips of the bicipital groove* below. The latter are the Pectoralis Major, Teres Major, Latissimus Dorsi. The Pectoralis Major and Teres Major are inserted into the rough crests, known as the lateral and medial lips respectively of the bicipital sulcus, that descend from the tuberosities and deepen the bicipital sulcus. The Latissimus Dorsi is inserted into the sulcus just lateral to the Teres Major. The surgical neck meets the anatomical neck medially, in the region of the quadrangular space; and slightly above the level of the surgical neck runs the epiphyseal line. (Cont'd. on p. 115).

The Deltoideus, shaped like the Greek letter delta inverted, would form with the Trapezius a continuous muscle sheet, were it not that the clavicle and scapula intervened between them. Thus, the deltoid arises from the anterior border of the flattened lateral third of the clavicle, where it is separated from the origin of the Pectoralis Major by the base of the infraclavicular fossa (delto-pectoral triangle), from the lateral border of the acromion, and from the lower lip of the crest of the spine of the scapula. From this extensive origin the muscle descends to its restricted and, therefore, fibrous insertion into the *deltoid tuberosity* of the humerus.

The Deltoid Tuberosity. This rough tuberosity spreads across the lateral surface of the bone and extends down to its middle point. About 1½″ long, it also has the form of an inverted delta. The anterior limb of this inverted delta, followed upwards, becomes continuous with the lateral lip of the bicipital sulcus, which extends to the front of the greater tuberosity. The posterior limb, followed upwards, becomes the rough line of origin of the lateral head of the Triceps, which leads towards the site of insertion of the Teres Minor into the back of the greater tuberosity. These extensions of the delta result in the upper half of the lateral surface of the humerus having the appearance of an inverted A. The anterior border of the deltoid tuberosity is part of the anterior border of the humerus, and is vertical; the posterior border forms the upper boundary of the *spiral groove* for the radial nerve, and is set obliquely.

Winding around the posterior border of the Deltoid below the middle of its length is the cutaneous branch of the circumflex nerve, called the *upper lateral cutaneous nerve of the arm.*

Detach the Deltoid from its origin and turn it downwards and thereby expose the circumflex nerve, accompanied by the posterior humeral circumflex artery, which adheres to the deep surface of the Deltoid and supplies it (*fig. 82*). Follow the nerve and vessel to the quadrangular space. Also exposed is the greater tuberosity and the bare area on the lateral surface of the humerus. This area is bounded by the limbs of the inverted A that give attachment to the Pectoralis Major and the lateral head of the Triceps respectively (*fig. 80*).

The Quadrangular Space is merely the lateral or basal portion of an *isoceles triangle* whose boundaries are: *above*, the axillary border of the scapula and the capsule of the shoulder joint; *laterally*, the surgical neck of the humerus; *below*, the Teres Major (*figs. 81, 82*). Since the axillary border of the scapula is clothed

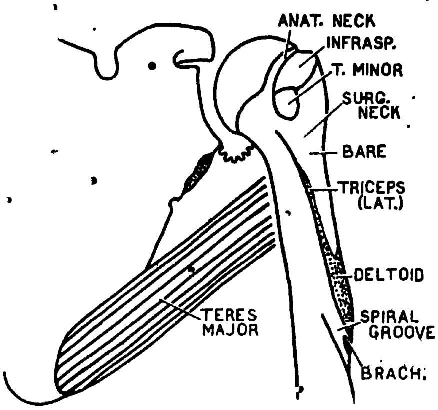


FIG. 81. Upper half of humerus (posterior view): The foundation of the quadrangular space.

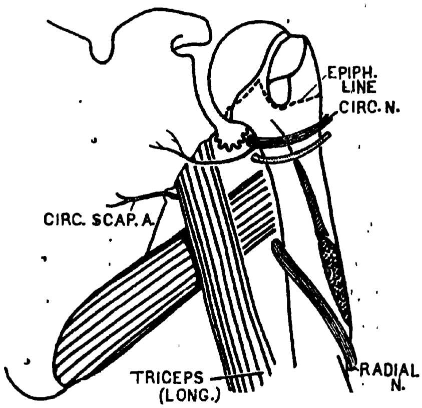


FIG. 82. The triangular and quadrangular spaces.

anteriorly by the Subscapularis and posteriorly by the Teres Minor, these two muscles assist in the formation of the upper boundary of the triangle; and, because their insertions into the humerus are far apart—the one, to the lesser

tuberosity, the other to the lowest impression on the greater tuberosity—it follows that the upper boundary of the triangle is very deep laterally, in fact it is equal to two-thirds of the circumference of the surgical neck (*fig. 170*). *The long or scapular head of the Triceps*, arising from the rough triangular infraglenoid tubercle of the scapula, divides this triangle into an apical and a basal portion, known respectively as the *triangular* and the *quadrangular space*.

Entering the triangular space is a large anastomotic artery, the *circumflex scapular branch* of the subscapular artery, which, on its way to the infraspinous fossa, grooves the axillary border of the scapula. Passing through the quadrangular space are the *circumflex nerve* and the *posterior humeral circumflex artery*.

The Circumflex Nerve (Axillary Nerve) **has two important relations:**

1. The capsule of the joint above.
2. The surgical neck of the humerus laterally.

As the circumflex nerve passes through the quadrangular space it sends twigs to the capsule of the joint; and, on leaving the space it supplies the Teres Minor. Thereafter, it supplies the Deltoid and the skin covering the Deltoid.

Distribution. This nerve, then, is distributed to the joint, to two muscles that act upon the joint, and to the skin covering the joint.

Surface Anatomy. On restoring the Deltoid to its natural position, observe that the circumflex nerve and companion artery wind round the surgical neck of the humerus and that their position would be indicated on the skin surface by a horizontal line drawn 2 inches below the angle of the acromion.

Parts Covered by the Acromion. When the deltoid is thrown down, it is not the fibrous capsule of the joint that you see but the tough tendons of three dorsal scapular muscles—Supraspinatus, Infraspinatus, and Teres Minor—which conceal and adhere to the capsule. Between the acromion and the Supraspinatus tendon is the *subacromial bursa*, which functionally plays the part of an accessory joint cavity. It is large, extending beyond the acromion laterally deep to the Deltoid, anteriorly deep to the coraco-acromial ligament, and sometimes medially deep to the Trapezius (*figs. 168, 171*).

The greater tuberosity of the humerus projects beyond the acromion. It is evident that it is to this projection, and not to the Deltoid which covers it, that the roundness of the shoulder is due, for when the joint is dislocated the roundness is lost, the acromion becomes the most lateral bony point, and the shoulder appears square. When the arm is abducted, the greater tuberosity passes completely under cover of the acromion; hence, the necessity for an extensive subacromial bursa.

Since the shoulder joint has but two muscles lying above it, it can evidently possess but *two abductors*: they are the Supraspinatus and the intermediate fibers of the Deltoid. Each is supplied by the 5th and 6th cervical nerve segments, the one via the suprascapular nerve; the other via the circumflex nerve.

The Structure of The Deltoid. If the deep aspect of the Deltoid be examined, 4 tendinous septa will be seen to descend in its substance (*fig. 83*). These spring from 4 small tubercles on the lateral border of the acromion. With a little dissection it will be seen that the muscle fibers that arise from each of these septa are arranged like the barbs on the

quill of a feather; hence, the architecture or internal structure of the Deltoid is said to be multipennate. The muscle fibers springing from the adjacent sides of two tendinous septa converge to be inserted into a third tendinous septum, which passes upwards from the Deltoid tuberosity to receive them. It is evident, then, that the muscles fibers of the intermediate part of the Deltoid are very numerous but very short. On this account it is very powerful, but its range of action is very short. The multipennate

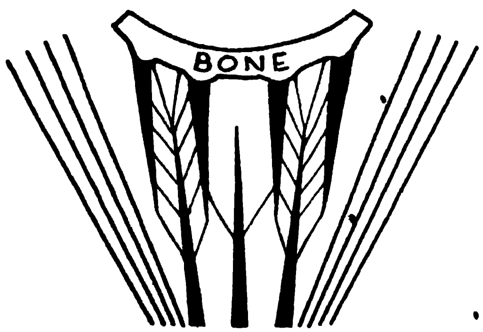


FIG. 83. Architecture or internal structure of Deltoid.

is the most powerful type of muscle in the body.

The anterior and posterior parts of the Deltoid have a different internal structure: they are composed of long parallel fibers because they take part in the more extensive movements of flexion and extension of the shoulder.

With a little care, each of the three portions of the muscle, each with its own vascular and nerve supply, can be separated from the other two.

The Subscapular Fossa. The concave area on the costal surface of the scapula, the *subscapular fossa*, is crossed by 3 or 4 oblique lines that converge on the glenoid cavity. From them spring fibrous partitions which extend into the Subscapularis and afford it a multipennate origin, similar to that of the Deltoid.

The tendon of the Subscapularis grooves the anterior margin of the glenoid cavity and helps to give it a pear-shaped appearance (*fig. 84*). This feature distinguishes the anterior border of the cavity from the posterior.

The Inferior Angle of the Scapula is thick and strong because three muscles act on it: the greater part of the Serratus Anterior being attached to its costal surface; the Teres Major to its dorsal surface; and the Rhomboid Major

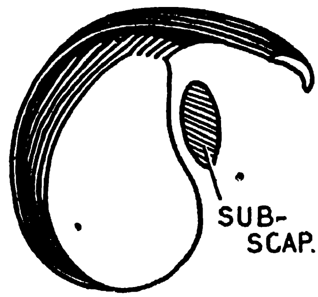


FIG. 84. Glenoid cavity, Biceps, and Subscapularis.

to the adjacent part of its medial border.

The inferior angle is situated at the extreme end of a lever and, therefore, at the most advantageous site for these three muscles to act (*fig. 85*).

The Axillary Border of the Scapula extends from glenoid cavity to inferior angle. It presents at its upper end a rough, triangular area, the *infraglenoid tubercle,* from which the long or scapular head of the Triceps arises. Running parallel to this border on the costal surface is a strong, smooth, rounded bar of bone. Its purpose is to insure that the axillary border shall neither buckle nor break when the Serratus Anterior is steadying the inferior angle of the scapula or pulling it forwards against resistance, as in raising a weight in front of the

body or when pushing (*fig. 86*). The Serratus and the axillary border are similarly employed by a quadruped when on all fours (*fig. 76*). The axillary bor-

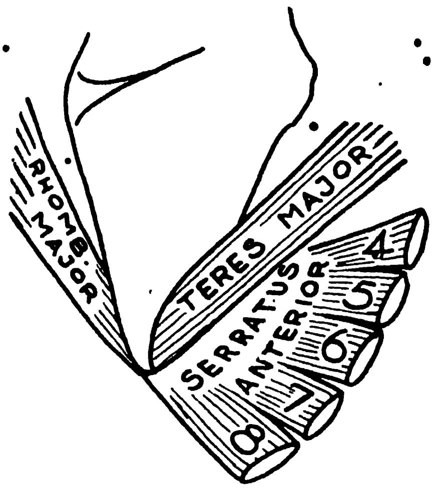


FIG. 85. Muscles attached to the end of the lever.

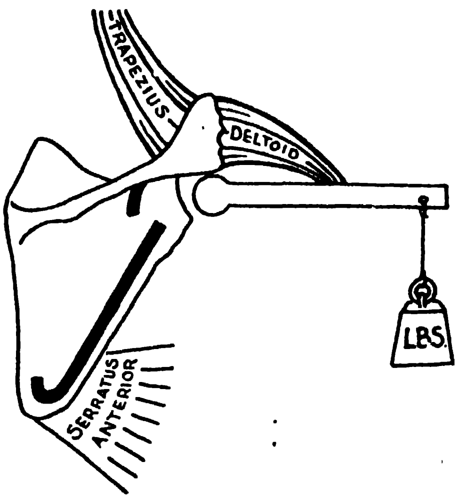


FIG. 86. The three chief muscles concerned in elevation of the limb: Two strengthening bars on the scapula.

der is, therefore, the strong border (*fig. 87*).

AXIOM. When muscle fibers contract they shorten by about a third or a half of their length, that is to say, if a muscle is to draw a load through one inch its fleshy fibers must be 2 to 3 inches long. For this reason the origins of the Subscapularis, Supraspinatus, and Infraspinatus do not extend right up to the margin of the glenoid cavity but leave the neck of the scapula free. By the term, *neck of the scapula*, is understood the part encircled by a line drawn from the suprascapular notch to the infra-

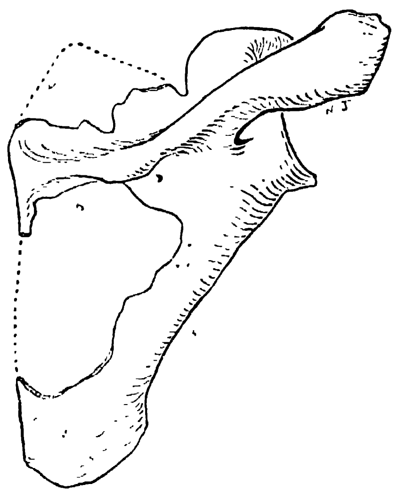


FIG. 87. The axillary border is the strong border; the others can be broken away with the fingers.

glenoid tubercle. The glenoid cavity and coracoid process are lateral to the neck.

The Teres Muscles. *Origins.* The *Teres Minor* arises from the dorsum of the axillary border of the scapula. The *Teres Major*, which is a very large muscle, arises from the large impression on the dorsum of the inferior angle and axillary border of the scapula and partly from the dense fascia covering the Infraspinatus.

Nerves Supply. Both muscles are supplied by nerve segments C, 5, 6, but via

different nerves. One is a lateral rotator of the humerus; the other is a medial rotator.

OBSERVE: (a) that the long head of the Triceps passes between the Teres Major and Teres Minor; (b) that the Teres Major passes between the circumflex and radial nerves; and (c) that the fibers of the Teres Major take a half spiral course, like those of the Latissimus Dorsi, and that the flat tendon of insertion of the Teres Major blends below with that of the Latissimus Dorsi, but is separated from it above by a bursa.

CHAPTER 4

THE CUTANEOUS NERVES AND VEINS OF THE UPPER LIMB

Cutaneous Nerves. GENERAL. The muscles of the upper limb are supplied by nerve segments C. 5, 6, 7, 8 and Th. 1 by way of the brachial plexus. The cutaneous supply is more extensive: it draws not only on the plexus, but also on two additional cephalic and two additional caudal segments. It comes from segments 3, 4—5, 6, 7, 8, 1—2, 3.

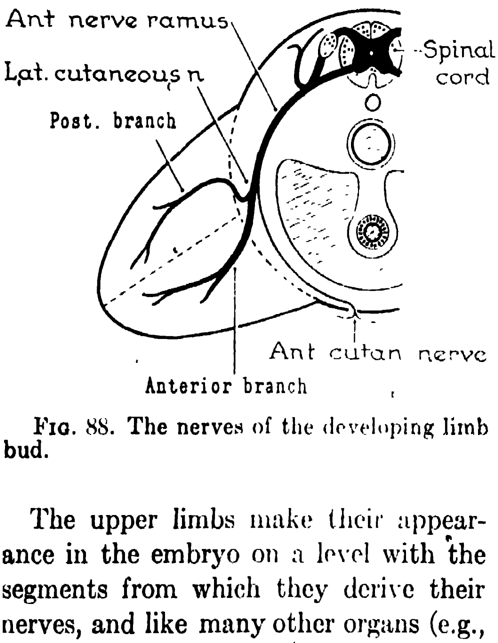


FIG. 88. The nerves of the developing limb bud.

The upper limbs make their appearance in the embryo on a level with the segments from which they derive their nerves, and like many other organs (e.g., heart, diaphragm, stomach, and sex glands) they descend, dragging their nerves after them. This explains the oblique course of the brachial plexus.

The limbs sprout and grow from the ventral half of the body; so, the brachial plexus of the upper limb and the lumbosacral plexus of the lower limb are derived from anterior nerve rami (*fig. 88*). And, it is probable that the anterior and posterior divisions and cords of the brachial plexus represent the anterior and posterior branches of lateral cutaneous nerves, shown in figure 68.

Initially the thumb and radius occupy the cephalic or *preaxial* border of the limb; the little finger and ulna occupy the caudal or *postaxial* border. Similarly, in the lower limb the big toe and tibia occupy the cephalic or preaxial border; the little toe and fibula occupy the caudal or postaxial border. Later the limbs undergo rotation in opposite directions with the result that the thumb and radius are carried laterally and the palm of the hand comes to face forwards; whilst the big toe and tibia are carried medially and the sole of the foot faces backwards (or downwards).

The nerve segments supply the skin in orderly numerical sequence from the shoulder down the preaxial border of the limb to the thumb; from the thumb to the little finger; and from the little finger up the postaxial border to the axilla (*figs. 89, 90*). Moreover, as shown in figure 91, which is a section through the forearm, the sequence is maintained from radial to ulnar border across both the front and the back of the limb. This proviso must however be made: the nerve to the middle segment of the plexus, namely the 7th cervical, is carried downwards in the substance of the limb and is not represented on the surface till the level of the wrist is reached on the front of the limb, and the elbow on the back of the limb. In consequence, proximal to these levels there is a hiatus in the serial succession of the nerves on the front of the limb and on the back.

It is a fundamental truth that the nerves to the muscles on the morphological ventral and dorsal surfaces of the

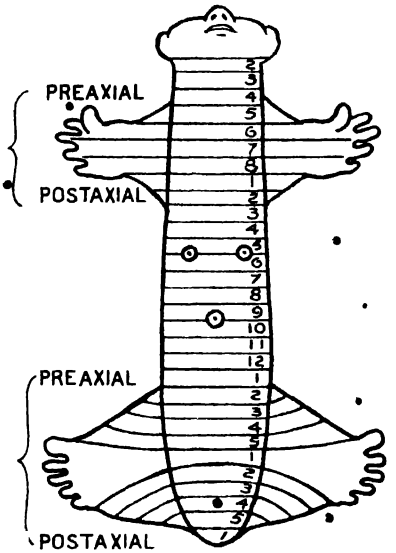


FIG. 89. Scheme of primitive segmental nerve distribution (After Purves Stewart.)

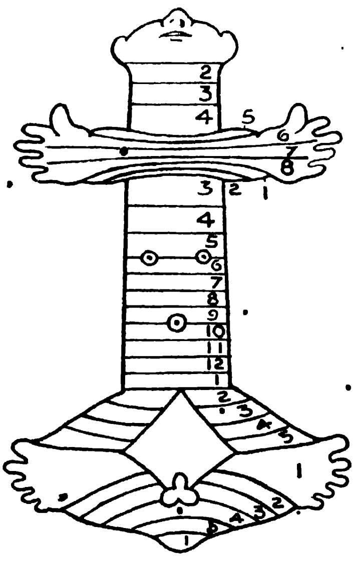


FIG. 90. A later stage of figure 89.

upper and lower limbs are derived from the anterior and posterior divisions respectively of the brachial and lumbosacral plexuses. Similarly, the cutaneous nerves on the morphological ventral and dorsal surfaces of the limbs, though taking certain liberties, are derived from the respective anterior and posterior divisions.

The skin over the upper part of the pectoral and shoulder regions would seem to have been drawn down from the neck, as a sheet of rubber might be drawn down, bringing with it the *supraclavicular nerves* (C. 3, 4); similarly, the skin of the axilla and of the medial side of the arm would seem to have been pulled off the chest bringing the *intercosto-brachial nerve* (Th. 2) and a branch from

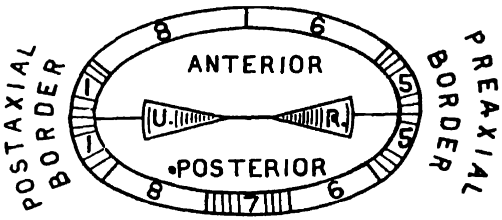


FIG. 91. Transverse section of forearm showing the segmental distribution of cutaneous nerves (schematic).

the lateral cutaneous branch of the *third intercostal nerve* (Th. 3) with it.

The Pectoral Region. Above the 2nd rib this region is supplied by the *supraclavicular nerves* (C. 3, 4); and below the 2nd rib by the *anterior cutaneous nerves* and anterior branches of the *lateral cutaneous nerves* (Th. 2–6).

The Axilla. The *intercosto-brachial* (Th. 2) and Th. 3 supply the skin at the base of the axilla.

The Shoulder. *Supraclavicular nerves* (C. 3, 4) cross the clavicle and acromion deep to the Platysma and supply the upper half of the deltoid region. The cutaneous branch of the *circumflex nerve* (C. 5, 6), known as the upper lateral cutaneous nerve of the arm, appears at the posterior border of the Deltoid below its midpoint and spreads forwards over

the lower half of the Deltoid; some twigs from the stem of the nerve pierce the Deltoid to become cutaneous. And, branches from the posterior rami, especially of 2nd thoracic, reach the back of the shoulder (*fig. 92*).

The Brachium or Arm. *The posterior cutaneous nerve of the arm* (C. 5, 6, 7, 8) arises from the radial nerve in front of the arm medial to the brachial artery. *The lower lateral cutaneous nerve of the arm* (C. 5, 6), also a branch of the radial nerve, becomes cutaneous where the spiral groove for the radial nerve crosses the lateral brachial intermuscular septum.

These four nerves of the arm all follow the lead of the cutaneous branch of the circumflex nerve in taking a spiral course.

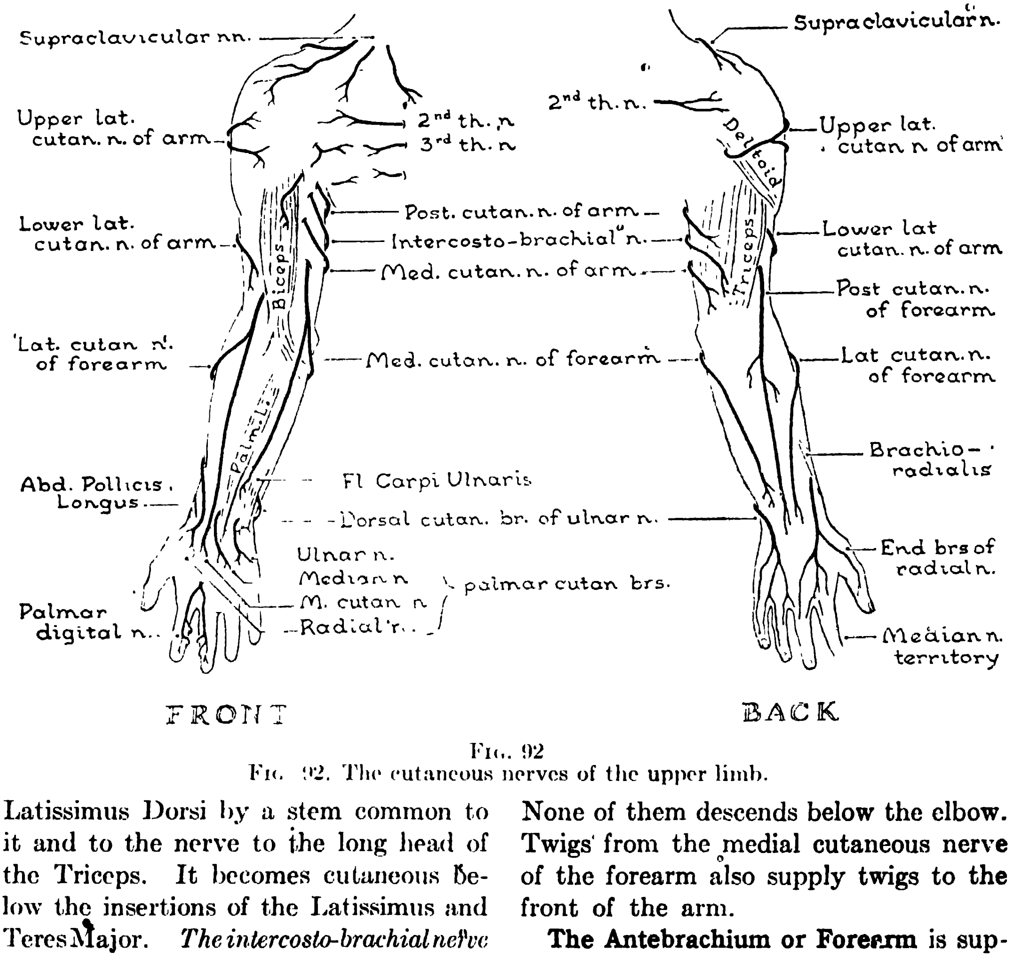


FIG. 92

FIG. 92. The cutaneous nerves of the upper limb.

Latissimus Dorsi by a stem common to it and to the nerve to the long head of the Triceps. It becomes cutaneous below the insertions of the Latissimus and Teres Major. *The intercosto-brachial nerve* (Th. 2) accompanied by a branch from the 3rd intercostal nerve pierces the fascial floor of the axilla and becomes cutaneous. *The medial cutaneous nerve of the arm* (C. 8 and Th. 1) springs from from the medial cord of the plexus and becomes cutaneous in the upper third of the arm. None of them descends below the elbow. Twigs from the medial cutaneous nerve of the forearm also supply twigs to the front of the arm.

The Antebrachium or Forearm is supplied by the *medial, lateral,* and *posterior cutaneous nerves of the forearm.* Each of these three cutaneous nerves is derived either directly or indirectly from the similarly named medial, lateral, and posterior cords of the brachial plexus. Each of the three outcrops on the surface

above the elbow. The medial and lateral cutaneous nerves divide into anterior and posterior branches; the posterior cutaneous nerve remains undivided. All five branches descend to the wrist. The anterior branch of the lateral cutaneous nerve constantly passes beyond the wrist; the posterior cutaneous nerve usually passes beyond the wrist; the posterior branch of the lateral cutaneous nerve occasionally does; the branches of the medial cutaneous nerve confine themselves to the forearm.

The medial cutaneous nerve of the forearm, a direct branch of the medial cord ((7) 8, 1), becomes cutaneous half way down the arm medial to the brachial artery, and in company with the basilic vein. It divides into an anterior and a posterior branch, both of which pass in front of the elbow and then descend on the front and back of the ulnar side of the forearm as far as the wrist. Its branches pass either superficial or deep to the median cubital vein and other cutaneous veins at the elbow. *The lateral cutaneous nerve of the forearm* is the terminal branch of the musculo-cutaneous nerve (C. 5, 6 (7)), and therefore of the lateral cord. It becomes cutaneous at the lateral border of the Biceps an inch or two above the elbow. Like the medial cutaneous nerve it divides into anterior and posterior branches which pass in front of the elbow before descending on the front and back of the radial side of the forearm; the anterior branch to reach the ball of the thumb, the posterior branch to end at or beyond the wrist. At the wrist both the anterior and the posterior branch commu nicate with the (superficial) radial nerve and the anterior branch sends a twig to the radial artery. *The posterior cutaneous nerve of the forearm*, a branch of the radial nerve and therefore of the posterior cord (C. 5, 6, 7, 8) becomes cutaneous along the line of the lateral intermuscular septum from 1″ to 3″ above the lateral epicondyle. It crosses behind the muscles arising from the lateral epicondylar ridge and descends in the middle of the back of the forearm to the wrist. It usually oversteps the wrist to reach the dorsum of the hand.

The Palm of the Hand. It will be recalled that each of the three cords of the brachial plexus divides into two terminal branches—namely, musculo-cutaneous and lateral root of median, medial root of median and ulnar, radial and circumflex nerves—making six in all. After the union of the two roots of the median these are reduced to five. Of these five nerves all, except the circumflex nerve, pass into the arm and each ultimately contributes a palmar cutaneous branch to the hand.

"*The palmar cutaneous branch of the musculo-cutaneous nerve*" (C. 6) ends on the ball of the thumb. It is usually known as the terminal branch of the anterior branch of the lateral cutaneous nerve of the forearm. *The palmar cutaneous branch of the median nerve* (C. 6, 7, 8) and the *palmar cutaneous branch of the ulnar nerve* (C. 8) become cutaneous proximal to the flexor retinaculum (transverse carpal ligament) on the lateral side of the Palmaris Longus and Flexor Carpi Ulnaris respectively. They cross in front of the flexor retinaculum and end in the palm. *The palmar cutaneous branch of the radial nerve* (C. 6, 7) follows the anterior border of the Abductor Pollicis Longus on to the ball of the thumb.

The most important cutaneous nerves of the hand, in fact the most important cutaneous nerves of the upper limb, are the *palmar digital branches of the median and ulnar nerves*. There are ten palmar digital branches—one for each side of

each digit. The lateral seven are branches of the median nerve, the medial three are branches of the ulnar nerve; that is to say, the median nerve supplies 3½ digits; the ulnar nerve 1½. The palmar digital branches furnish branches to the entire palmar surfaces of the digits, to the subungual regions (i.e., deep to the nail) and to the local joints. The median nerve is especially generous in its supply of branches to the dorsum of the index and middle fingers (*fig. 93*).

To expose a palmar digital nerve you should feel for the edge of a phalanx and make a longitudinal incision in front of it, because the nerves run on the sides of nerve supplies 1½ digits: The radial supplies the remainder, except for the subungual regions of the lateral 3½ digits, and the distal parts of the index and middle fingers and half the ring finger which the median nerve supplies (*fig. 94*). The radial nerve supplies twigs to the joints in its territory.

Variations in Pattern. Now, as it is the prime duty of the anterior cords (medial and lateral cords) to supply the front of the limb and of the posterior cord to cater for the back; the ulnar nerve in sending branches to the back of the hand is encroaching on "posterior cord" territory which should by rights be supplied

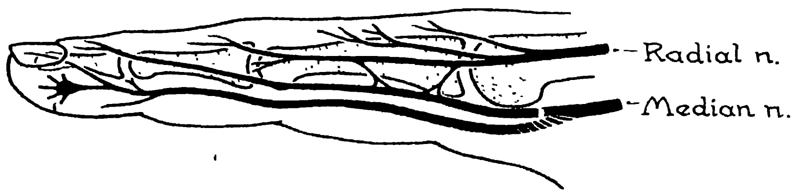


FIG. 93. Digital nerves of the index. (From a dissection by M. Wellman)

the fibrous flexor sheaths antero-medial to their accompanying arteries. A longitudinal incision that strikes bone is behind the nerve and misses it (see fig. 144).

The Dorsum of the Hand is supplied by the radial, ulnar and median nerves. *The dorsal cutaneous branch of the ulnar nerve* (C. 7, 8) and *the terminal branch of the radial nerve* (C. 6, 7), after passing deep to the Flexor Carpi Ulnaris and Brachio-radialis respectively, outcrop on the surface at the posterior borders of these muscles from one to four inches above the corresponding styloid process The dorsal branch of the ulnar nerve reaches the dorsum of the hand by crossing the medial (ulnar collateral) ligament of the wrist; the superficial radial nerve by crossing the "snuffbox". On the back of the hand they communicate. As at the front so at the back, the ulnar by the radial nerve. The discrepancy, however, is more apparent than real, for the dorsal cutaneous branch of the ulnar nerve is composed of fibers, which should have passed via the lowest of the three posterior divisions of the brachial plexus (8, 1) into the posterior cord and so to the radial nerve, but which elected the more direct pathway of the ulnar nerve. In this instance the ulnar nerve may be said to accommodate the radial nerve. Occasionally the radial nerve assumes its full responsibilities by supplying the entire dorsum of hand and digits—in such cases the dorsal branch of the ulnar nerve is wanting.

Dorsal Patterns: The cutaneous supply for the back of the hand has several patterns, thus: (a) the radial and ulnar nerves may increase or diminish their territories; (b) the posterior cutaneous

nerve of the forearm commonly invades the dorsum of the hand; (c) the dorsal branch of the lateral cutaneous nerve of the forearm may do so, even to the extent of completely replacing the cutaneous branch of the radial nerve (Appleton) (*fig. 95*). (d) The radial nerve

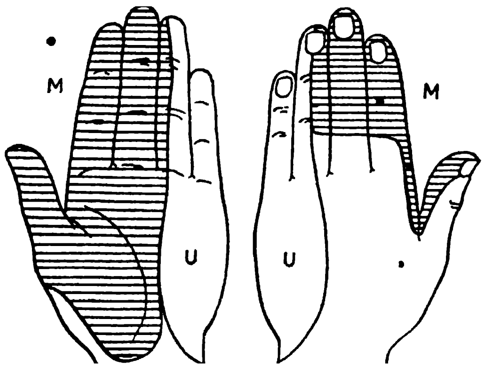


FIG 94 Distribution of median and ulnar nerves in the hand. (After Stopford.)

side of the ring finger; occasionally it includes the ulnar side of the middle finger and rarely the entire middle finger. Conversely the median nerve occasionally takes over the entire supply of the ring finger.

Axiom. Perhaps there is too great a tendency to search for the cutaneous nerves of the limbs at prescribed horizontal levels. Most of the cutaneous nerves of the upper limb are constant in becoming cutaneous at the borders of muscles which here run longitudinally, but the *level at which they become cutaneous varies* by as much as several inches; examples shown in figure 92 are:

The upper lateral brachial cutaneous n. at the posterior border of the Deltoid.

The lower lateral brachial cutaneous n. and

The posterior antebrachial cutaneous n. between the Triceps and Brachio-

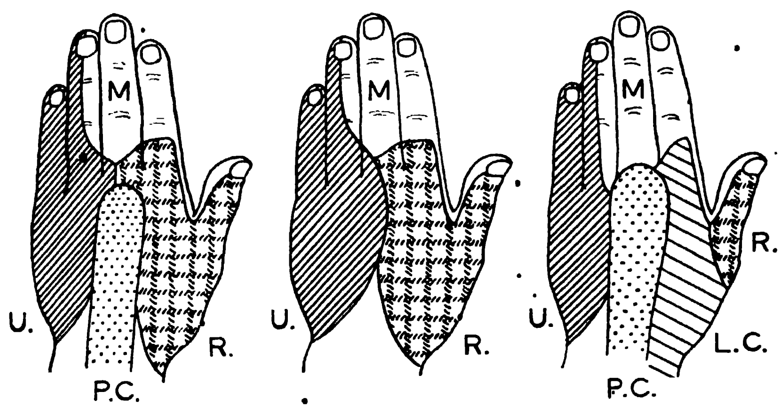


FIG. 95. **Patterns of cutaneous nerve distribution to the dorsum of the hand. (After Stopford)**

commonly supplies the subungual region of the thumb.

Palmar Patterns: The digital branches of the ulnar and median nerves to the ring finger always communicate in the palm. Via this communication the ulnar nerve commonly (14 per cent, Stopford) extends its territory to include the radial

radialis along the line of the lateral intermuscular septum.

The lateral antebrachial cutaneous n. at the lateral border of the Biceps.

The superficial branch of the radial n. at the posterior border of the Brachioradialis.

The palmar cutaneous branch of the

median n. at the lateral border of the Palmaris Longus.

The palmar cutaneous branch of the ulnar n. at the lateral border of the Fl. Carpi Ulnaris.

The dorsal branch of the ulnar n. at the medial border of the Fl. Carpi Ulnaris.

In these instances you should think vertically and act vertically—not horizontally—because the border is constant or practically so; the level is inconstant.

Superficial Veins. The superficial veins are generally visible through the skin in the male; if not, they can readily be made so by swinging (circumducting) the arm vigorously at the shoulder joint, ending with the limb dependent and below the level of the heart. In a stout, anaemic person it may be necessary to obstruct the venous return by encircling the arm with a tourniquet lightly so that the veins are obstructed but not the arteries. It may also be necessary to bandage the limb from hand to elbow in order to drive the contained blood to the region below the tourniquet.

The veins form many patterns. The *dorsal venous arch* on the back of the hand receives *digital branches*. It ends medially as the basilic vein and laterally as the cephalic vein. The *basilic vein* ascends on the ulnar side of the forearm to the elbow and then in the medial bicipital furrow to the middle of the arm where it pierces the deep fascia. It then accompanies the brachial artery and its venae comitantes to the axilla and becomes the axillary vein.

The *cephalic vein* crosses "the snuff-box" (that is the depression at the side of the wrist proximal to the base of the metacarpal of the thumb) superficial to the branches of the radial nerve. It ascends on the radial border of the forearm; in the lateral bicipital furrow of the arm; and in the cleft between the Deltoid and Pectoralis Major at the shoulder. It pierces the infraclavicular fossa (deltopectoral triangle) and, after crossing superficial to the Pectoralis Minor and costo-coracoid membrane, which separate it from the lateral cord of the plexus and the axillary artery, it ends in the axillary vein. It passes either in front of or behind the lateral pectoral nerve.

In the embryo, the cephalic vein crosses in front of the clavicle and ends in the external jugular vein; it may continue to do so in postnatal life.

A small vein, the *median vein*, runs up the front of the forearm and, after communicating with a *deep vein*, bifurcates into a medial and a lateral branch, which join the basilic and cephalic veins respectively. The M-like pattern so-formed recalls the roots of the median nerve. More commonly, however, a large oblique vein, the *median cubital vein*, placed in front of the elbow, joins the cephalic vein to the basilic vein.

The practitioner of to-day employs the median cubital vein in blood-transfusion; the barber of former days employed it in blood-letting. Hence the barber's sign—red and white wound spirally on a pole and a brass dish hanging from the pole. The pole for the patient to grasp; white for the bandage; red for blood; the dish to catch the blood.

RELATIONS: The median cubital vein passes in front of the bicipital aponeurosis which separates it from the brachial artery and median nerve; and it passes in front of (or between) the branches of the medial cutaneous nerve of the forearm.

VALVES: With the nail of your index finger obstruct any conspicuous vein in your forearm and expel the blood from it by stroking proximally with your thumb nail. Note that after removing the thumb the vein remains collapsed due to the presence of valves which prevent

reflux of blood, and that on removing the index the vein fills from below. (*Fig. 37.*)

THE UPPER ARM AND THE FRONT OF THE ELBOW

The Lower End of the Humerus. The lower articular end of the humerus is divided into two areas: the *capitulum* for the head of the radius and the *trochlea* for the trochlear (semilunar) notch of the ulna. One is spheroidal; the other is shaped like a spool (*fig. 96*). Immediately above and wide of these two condylar or knuckle-like articular areas are two projections, the *medial* and *lateral epicondyles*. The medial epicondyle can easily be grasped between the finger and thumb; the posterior surface of the less prominent lateral epicondyle is smooth, subcutaneous, and palpable. There are also 3 depressions: two small ones in front, the *radial* and *coronoid fossae*, which receive the margin of the head of the radius and the tip of the coronoid process of the ulna when the elbow is fully flexed; and a large triangular one behind, the *olecranon fossa*, which receives the olecranon of the ulna when the elbow is extended.

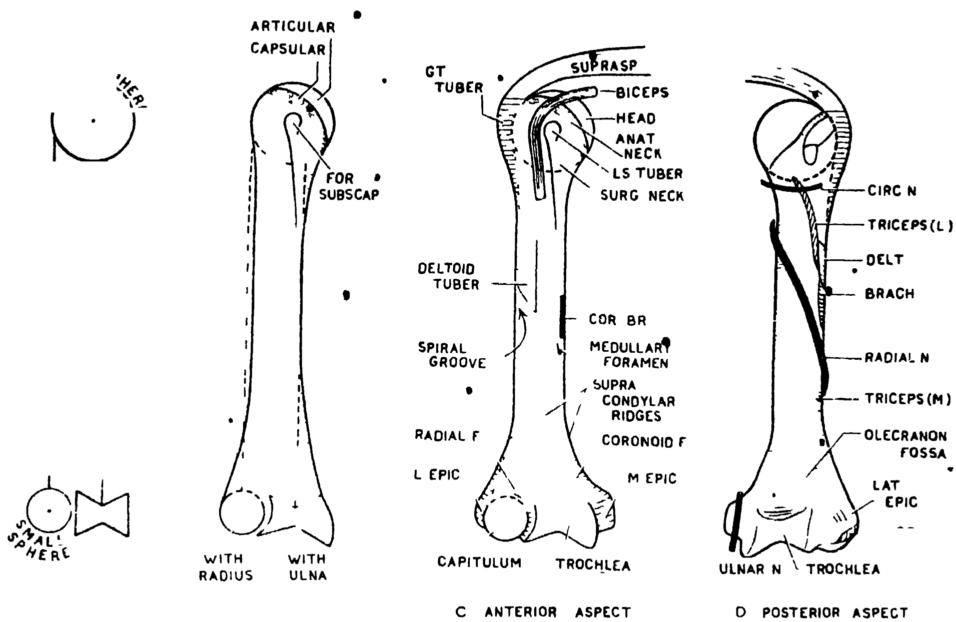


FIG. 96. A, B and C represent progressive stages in sketching a humerus from the front. D. Posterior aspect showing attachments of muscles and contacts with nerves.

The Lower Half of the Body of the Humerus is flattened from before backwards and is divided by the medial and lateral supracondylar ridges into an *anterior* and a *posterior aspect*. The medial and lateral *supracondylar ridges* ascend from the epicondyles and afford attachment to the medial and lateral intermuscular septa. The lateral and more prominent ridge extends to a broad, shallow groove, the *spiral groove*, which intervenes between the ridge and the *deltoid tuberosity*. The medial ridge rises to approximately the same level as the

lateral one, and there for an inch gives place to a linear roughness, the site of *insertion of the Coraco-brachialis.*

Though the lower half of the humerus is flattened, it is nevertheless not flat. A flat sheet of metal will bend or break; a corrugated sheet will not. Now, this anterior aspect of this lower half of the bone has a smooth corrugation (*fig. 97*). This corrugation or rounded strengthening bar of bone extends from the interval between the radial and coronoid fossae

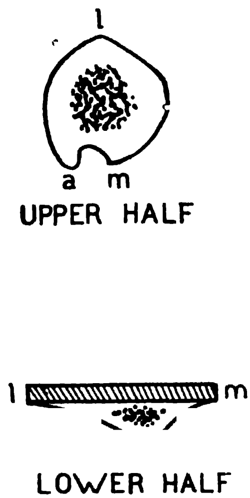


FIG. 97. Sections of humerus: the borders are indicated by letters.

to the anterior margin of the deltoid tuberosity. It is continuous in the upper half of the bone with the lateral lip of the bicipital groove, which extends from the deltoid tuberosity to the anterior part of the greater tuberosity. These 3—the rounded bar, the anterior border of the deltoid tuberosity, and the lateral lip of the bicipital groove—constitute the *anterior border* of the humerus (*fig. 98*).

The smooth, rounded bar performs the same strengthening function as the smooth, rounded, lateral border of the spine of the scapula and the smooth, rounded bar running parallel to the axillary border of the scapula. Its presence causes the lower half of the bone to be somewhat triangular on cross-section and it subdivides the anterior aspect into a medial and a lateral surface. These surfaces are entirely devoted to fleshy fibers of the Brachialis; so, they are smooth. The lower half of the *posterior surface* is entirely devoted to fleshy fibers of the medial head of the Triceps; so, it also is smooth.

The Upper Half of the Body of the Humerus is cylindrical in shape and, therefore, circular on cross-section, and it possesses 3 vertical lines for the at-

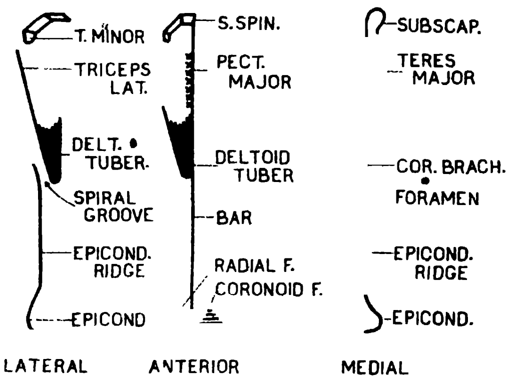


FIG. 98. **The borders of the humerus.**

tachment of aponeuroses of muscles; otherwise it is bare.

For descriptive purposes the three vertical lines form the upper portions of the anterior, medial, and lateral borders of the bone. The lateral lip of the bicipital (intertubercular) sulcus, caused by the insertion of the Pectoralis Major, is part of the anterior border described above. The medial lip of this sulcus, caused by the Teres Major (and Latissimus Dorsi) is part of the medial border (*figs. 79, 80, 81*). *The medial border* extends from the lesser tuberosity, where the Subscapularis is inserted, to the medial epicondyle. It includes the medial (epi-)

supracondylar ridge, the line of insertion of the Coraco-brachialis, and the medial lip of the bicipital groove. The third and least well marked of these lines, caused by the attachment of the lateral head of the Triceps, is part of the lateral border. *The lateral border* extends from near the lowest facet on the greater tuberosity, where the Teres Minor is inserted, to the lateral epicondyle. It includes the lateral supracondylar ridge, the posterior margin of the deltoid tuberosity, and the line of origin of the lateral head of the Triceps. And it is interrupted by the spiral groove wherein lodges the radial nerve.[3]

From these considerations it is evident that the *Deltoid* extends across the entire breadth of the lateral surface and takes part in the anterior and lateral borders, and that the *bicipital groove*, wherein lodges the long tendon of the Biceps, forms the upper part of the medial surface of the humerus. It also forms the lateral wall of the axilla.

Fascia. The arm or brachium is enveloped in a sleeve of tough deep fascia whose fibers take a more or less circular course. It is divided into an anterior and a posterior compartment by the medial and lateral intermuscular septa which pass from the deep enveloping fascia to the supracondylar ridges (*fig. 99*).

Muscles. In the anterior compartment there are three muscles—Coraco-brachialis, Biceps Brachii, and Brachialis. In the posterior compartment there is one muscle—Triceps Brachii.

THE CORACO-BRACHIALIS shares the tip of the coracoid process with the *short head of the Biceps;* so, both have tendinous origins. The roughness at the middle of the medial border of the humerus denoting the site of insertion of the Coraco-brachialis has been observed.

THE LONG HEAD OF THE BICEPS springs from the supraglenoid tubercle and posterior rim of the glenoid cavity (*fig. 84*). Its tendon curves across the front of the head of the humerus, as will be seen when the shoulder joint is studied, and then

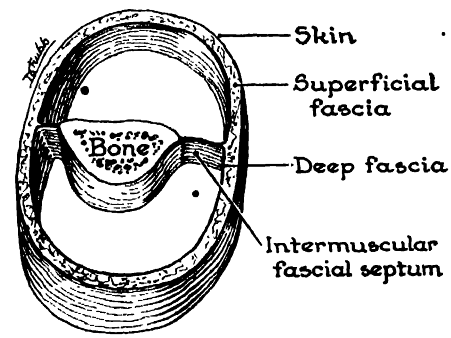


FIG. 99. The 2 compartments of the upper arm.

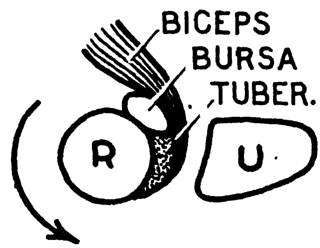


FIG. 100. The insertion of the Biceps: The Biceps supinates.

descends in the bicipital groove, encased in a tubular *bursa*, continuous with the synovial cavity of the shoulder joint.

The long and short heads unite about the middle of the arm. Their common tendon is inserted into the posterior, rough half of the tuberosity of the radius, which is situated just below the medial side of the neck of the radius (*fig. 100*); so, when the Biceps contracts, as when driving in a screwnail or corkscrew, it unrolls or supinates the radius. A *bursa*

[3] In reality the nerve is protected in part by fleshy fibres of the medial head of the Triceps.

is required between the tendon and the smooth anterior part of the olive-shaped tuberosity. The biceps is also inserted into the fascia covering the flexor muscles by means of a fibrous band, the *bicipital aponeurosis* (lacertus fibrosus).

When the long head of the Biceps, accompanied on its medial side by the short or coracoid head, passes beyond the bicipital groove, it comes to lie in front of the Brachialis and ceases to be tendinous.

THE BRACHIALIS arises from the entire breadth of the anterior aspect of the lower half of the humerus (i.e., lateral surface, anterior border, and medial surface) and the origin splits into two limbs at the insertion of the Deltoid. One limb largely fills the spiral groove; the other extends upwards between insertions of the Deltoid and Coraco-brachialis almost to the insertion of the Teres Major (*fig. 103*). Seeing the axilla ends at the lower border of the Teres Major, it follows that the Brachialis extends almost to the axilla. Its origin is fleshy; so, the underlying bone is smooth. Its restricted and therefore fibrous insertion produces a rough elevation (tuberosity of the ulna) on the anterior aspect of the coronoid process of the ulna.

Actions. (1) The Coraco-brachialis passes from scapula to humerus. It flexes and adducts the shoulder joint. (2) The Brachialis passes from humerus to ulna. It flexes the elbow joint. (3) The Biceps passes from scapula to radius. It can do by itself what the Coraco-brachialis and Brachialis do together; moreover, as has just been explained, it is a powerful supinator of the radio-ulnar joints.

Nerve Supply. These 3 muscles and these 3 only are supplied by the musculocutaneous nerve (*fig. 158*).

THE TRICEPS BRACHII: Its *long* or scapular head, being tendinous, springs from a rough impression, the *infraglenoid tubercle*, situated on the axillary border of the scapula immediately below the glenoid cavity. This head separates the triangular space from the quadrangular space. It also separates two muscles that have opposite rotary actions, namely, the Teres Major and Teres Minor. The Triceps has two humeral heads, a *medial* and a *lateral*; of these the medial head arises by fleshy fibers from the entire posterior surface of the humerus below the level of the spiral groove. The lateral head is largely tendinous and is responsible for the line that ascends from the posterior margin of the deltoid tuberosity. It also arises from a fibrous arch that bridges the spiral groove.

The common tendon of insertion is attached to the posterior half of the upper surface of the olecranon, a *bursa* intervening between it and the capsule of the elbow joint. Some fibers sweep distally into the deep fascia that covers the Anconeus, thereby forming the "*tricipital aponeurosis*".

Action and Function. The Triceps is the extensor of the elbow joint. Its chief function or use is to keep the extended elbow extended (i.e., to prevent it from flexing) when one is pushing an object.

Nerve Supply. All 3 heads are supplied by the radial nerve (*fig. 157*).

Structures around the Elbow. Before you examine the vessels and nerves of the arm, it is more than desirable that you become familiar with the disposition of the structures around the elbow. There is a two-fold reason for this: (1) Almost every important structure at the elbow can be palpated in the living subject. You can, therefore, at any time roll up your sleeve, palpate, and thereby refresh

your memory. (2) On this account the region assumes a key position both to the front of the upper arm and to the front of the forearm. Therefore, identify the structures by palpation and confirm

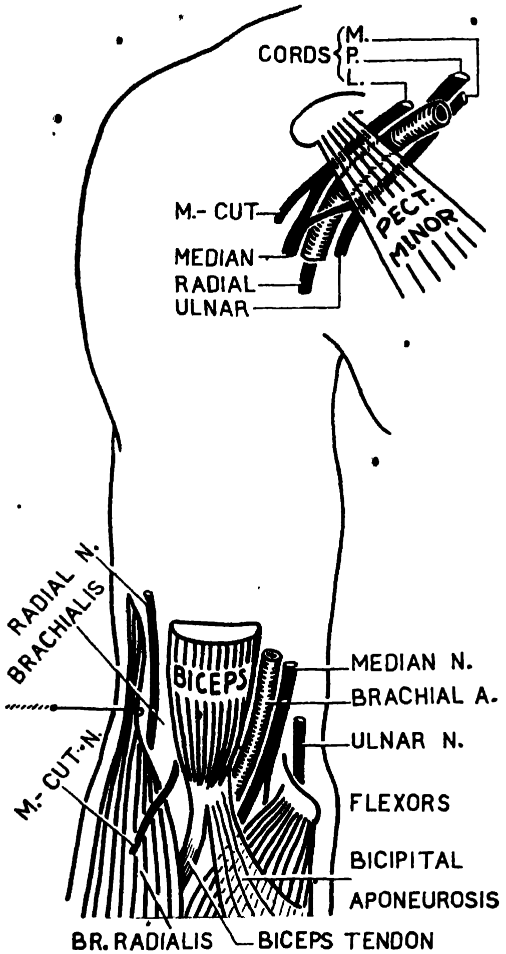


FIG. 101. Two key positions.

their positions by dissection (*figs. 101, 102*) thus:

When the elbow is flexed to a right angle and the forearm forcibly supinated (the palm of the hand then faces upwards), the *Biceps tendon* and the *bicipital aponeurosis* stand out at the middle of the front of the elbow as a prominent central landmark, ¾ inch in width. They can be grasped between the index finger and the thumb. When the Biceps is "relaxed" (rest forearm on the table) the pulsations of the *brachial artery* can be felt just medial to the Biceps tendon; and with the tips of the fingers the *median nerve*, which lies just medial to the artery, can be rolled on the Brachialis. The *ulnar nerve*, lying behind the medial epicondyle, can be felt to slip from under the finger tips as they are drawn across it. It can be traced half way up the arm. With the tips of two or three fingers the lateral supracondylar ridge can be traced to the spiral groove, and an endeavor made to roll the *radial*

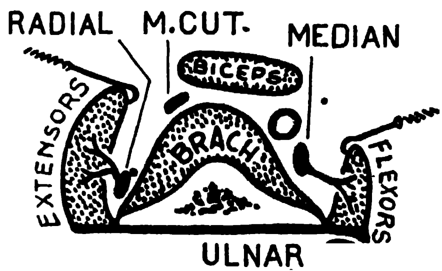


FIG. 102. Section showing nerves at elbow. Note their "sides of safety".

nerve against the bone. For success in this, it must be appreciated that the course of the nerve is almost vertical. The *musculo-cutaneous nerve* appears at the lateral border of the Biceps, one or two inches above the bend of the elbow, and becomes the lateral cutaneous nerve of the forearm.

Though easily located, it is not easily palpated. With the elbow bent to a right angle and the palm of the hand facing the body (that is, midway between pronation and supination, as you would carry it loosely in a sling) the *two muscles* (Brachio-radialis and Ex. Carpi Radialis Longus) that spring from the lateral supracondylar ridge can be grasped between fingers and thumb. If this fails to render them prominent, placing the

radial edge of the closed fist under the edge of a heavy table and trying to lift it will cause the muscles to stand out. If you could open up the space between the two muscles that lie laterally and

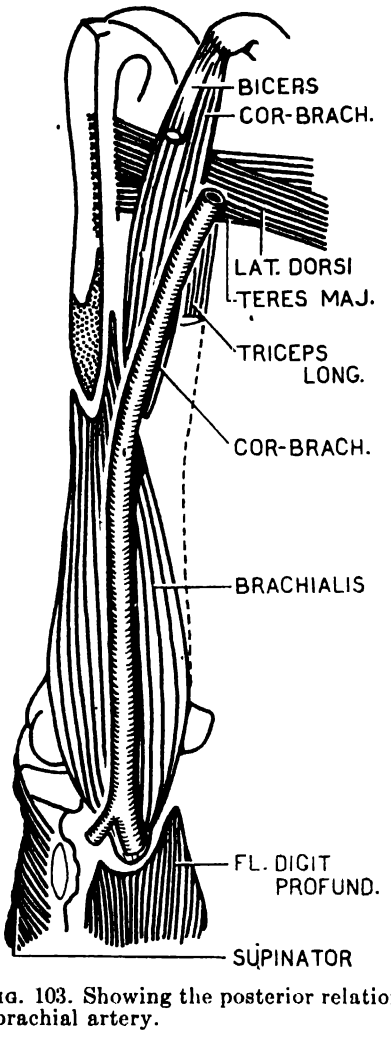


FIG. 103. Showing the posterior relations of the brachial artery.

the Branchialis, which lies medial to them, you would see the radial nerve in the depths. The bicipital aponeurosis (lacertus fibrosus) prevents the flexor muscles, which spring from the medial epicondyle, from being grasped.

The Brachial Artery. When the relations of the structures in this key position are established in your mind, you may return to a former landmark, the *Pectoralis Minor* (*fig. 101*). Behind the Pectoralis Minor you saw three cords of the brachial plexus arranged around the axillary artery according as they are named —medial, lateral, posterior. The *axillary vein*, which is the upward continuation of the basilic vein, lay medial to the artery. The artery lay a finger's breadth from the tip of the coracoid process.

The axillary artery, after crossing the Subscapularis, Latissimus Dorsi, and Teres Major, enters the arm as the brachial (*fig. 103*).

The brachial artery is the largest artery whose pulsation and whose walls can be felt satisfactorily in the living subject. It may be palpated along the medial bicipital furrow throughout the length of the arm to the point where it disappears behind the bicipital aponeurosis. At the level of the neck of the radius, one inch below the transverse crease of the elbow, it divides into its two terminal branches, a larger *ulnar artery* and smaller *radial artery* In the upper part of its subfascial course it lies medial to the humerus; therefore, to occlude it you must press laterally. In the lower part of its course it lies anterior to the humerus; therefore, to occlude it you must press backwards. Its upper one-third has the long head of the Triceps and the insertion of the Coraco-brachialis behind it; its lower two-thirds, that is 67 per cent of its length, has the Brachialis behind it.

Its *collateral branches* are: muscular, profunda brachii, ulnar collateral, medullary, and supratrochlear (inferior ulnar collateral). Their special interest lies in the anastomoses they effect around the shoulder and elbow (*fig. 185*).

Venae comitantes accompany the brachial artery and make a very open net-

work around it. They end in the axillary vein.

Nerves. You have now to ask yourself which of the terminal and which of the collateral branches of the brachial plexus cross the lower border of the Teres Major; for they have to be accounted for in the arm. It is not difficult to decide that of the six terminal branches, 5 must cross the boundary and enter the arm, for you have already identified them around the elbow. They are the musculocutaneous, the ulnar, the two roots of the median (or the median itself), and the radial nerves. Only one, the circumflex nerve, disappears at the upper border of the Teres Major and so fails to enter the arm. Two collateral branches (medial cutaneous of the arm, medial cutaneous of the forearm) have already been considered, so has the branch of the radial nerve which divides into the nerve to the long head of the Triceps and the posterior cutaneous nerve of the arm.

At first, the branches of the brachial plexus that enter the arm naturally bear the same direct relationship to the 3rd part of the axillary artery and beginning of the brachial artery as the cords from which they spring bear to the 2nd part of the axillary artery. The two roots of the median nerve, however, unite almost at once in front of (or rather towards the lateral side of) the artery.

The Musculo-cutaneous Nerve arises from the lateral cord of the plexus (5, 6, 7) and extends to the lateral border of the Biceps, an inch or more above the transverse crease of the elbow. It soon pierces the deep fascia to become the *lateral cutaneous nerve of the forearm*. It, therefore, must course distally and lateralwards. It pierces the Coraco-brachialis and continues between the Biceps and Brachialis; and it supplies these three muscles. It generally supplies and pierces the Coraco-brachialis while in the axilla; therefore, though it lies lateral to the brachial artery, it is a short distance from it.

Commonly, many of the fibers that the lateral cord should contribute to the median nerve elect to travel with the musculo-cutaneous nerve for a variable distance, even as far as the lower third of the arm, before joining the median nerve. (*Fig. 158.*)

The Ulnar Nerve arises from the medial cord of the plexus ((7), 8, 1) and extends to the back of the medial epicondyle, and onwards into the forearm. It, therefore, must pass distally and medially. It is applied to the medial side of the great arterial stem till it reaches the middle of the arm. There it leaves the artery and passes behind the medial intermuscular septum into the posterior compartment of the arm, where it lies subfascially applied to the medial head of the Triceps. You have palpated it in the distal half of the arm. Accompanying it behind the septum are the (superior) ulnar collateral artery and a branch called the ulnar collateral nerve, sent by the radial nerve to the medial head of the Triceps.

The ulnar nerve neither gives nor receives branches in the arm but makes a "non-stop" journey through it.

The Median Nerve. Its two roots ((5), 6, 7 and 8, 1) unite a little below the Pectoralis Minor, in front of—or rather to the lateral side of—the artery. You have rolled it on the Brachialis medial to the artery at the elbow; so, evidently it crosses the artery very obliquely. Does the crossing take place behind the artery or in front of it? Usually in front (in the ratio of 7:1). This is explained by the fact that the brachial artery was represented in embryonic life by two vessels, and the median nerve passed

between them. In cases where the anterior vessel disappears, the nerve crosses in front; in cases where the posterior vessel disappears, it crosses behind; where both vessels persist, the nerve passes between them (*fig. 104*). Furthermore, when both vessels persist, one is usually continued into the forearm as the radial artery, the other as the ulnar. This is spoken of as a *high division of the brachial artery.*

The median nerve gives off no branches in the arm—unless a muscular branch to the flexors arises unusually high. It commonly receives communications from

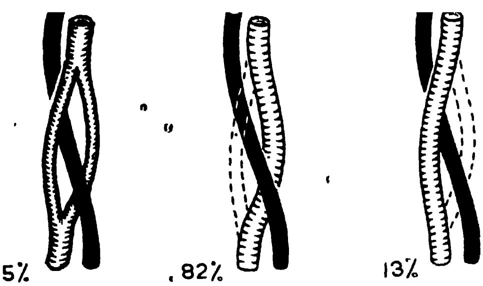


FIG. 104. Explaining the variable relationship of the median nerve to the brachial artery. Percentages are based on 307 limbs.

the musculo-cutaneous (i.e., accessory roots) and occasionally gives branches to it; and, strictly speaking, the formation of the median nerve is not completed until the last communication from the musculo-cutaneous has joined it. After crossing the artery in the middle of the arm, the median nerve assumes the position held by the ulnar nerve above this level.

The Radial Nerve, being a terminal branch of the posterior cord (5, 6, 7, 8 (1)), lies behind the axillary artery and in front of the Subscapularis, Latissimus Dorsi, and Teres Major. On entering the arm, it still lies behind the main arterial stem and is in front of the long head of the Triceps.

You have already palpated the nerve at the lateral side of the arm and have exposed it in the depths between the Brachio-radialis (which overlaps it) and the Brachialis. It lies on the capsule of the elbow joint and on the Supinator. At a variable point it divides into two terminal branches: (1) a sensory branch, the (*superficial*) *radial nerve*, and (2) a branch that is essentially motor, the *posterior interosseous nerve* (deep radial n). The latter disappears into the substance of the Supinator just below the elbow (*fig. 147*). In this course, branches pass from the radial and posterior interosseous nerves to 4 muscles — Brachio-radialis, Ex. Carpi Radialis Longus, Ex Carpi Radialis Brevis, and Supinator. Obviously, these branches pass from the lateral sides of the nerves; hence, the medial side is the safe side on which to dissect (*fig. 102*). Branches pass to the elbow joint and a twig passes to the Brachialis.

You have now to trace the radial nerve through the posterior compartment of the arm. On leaving the long head of the Triceps, the nerve enters the wide, spiral groove of the humerus, but does not nearly fill it. This groove is converted into a tunnel by the lateral head of the Triceps and the lateral intermuscular septum. Within the tunnel, the radial nerve descends almost vertically along the origin of the medial head of the Triceps, which lies medially (*fig. 96, D*) and the origins of the lateral head of the Triceps and the Brachialis, which lie laterally. On escaping from the tunnel, the radial nerve re-enters the anterior compartment of the arm and continues its nearly vertical descent deep to the Brachio-radialis.

It is a common fault to dissect for the nerve along the posterior border of the

Deltoid, forgetting that the Brachialis extends well up the groove (*fig. 103*).

BRANCHES (*fig. 157*). *In the axilla*, the branch to the long head of the Triceps arises with the posterior cutaneous n. of the arm.

At *the medial side of the arm*, a branch to the medial head of the Triceps (ulnar collateral n.) descends with the ulnar n. behind the medial intermuscular septum.

At *the back of the arm*, branches arise high up for the humeral heads of the Triceps and the Anconaeus; the lower lateral cutaneous n. of the arm and the posterior cutaneous n. of the forearm arise lower.

At *the lateral side of the arm and front of the elbow*, branches pass to the Brachioradialis, Ex. C. Radialis Longus, and elbow joint; a twig passes to the Brachialis; and branches pass from the posterior interosseous n. to the Ex. C. Radialis Brevis and Supinator.

All muscles supplied by the radial n. and its branches belong developmentally to the back of the limb; and all muscles supplied by the musculo-cutaneous, median, and ulnar nerves belong developmentally to the front, as explained (page 109).

AXIOM. The level at which motor (and sensory) branches leave a nerve is very variable; but the side from which they leave is constant—naturally, they leave from the side nearest the muscles to which they are distributed. Certain nerves have *sides of safety* and *sides of danger*; sides on which it is safe to dissect and sides on which it is dangerous. The median and radial nerves at the elbow exemplify this rule. The median nerve supplies flexors, therefore its branches pass medially; the radial nerve supplies extensors, therefore its branches pass laterally (*fig. 102*). It is, therefore, safe, or relatively safe, to dissect on the lateral side of the median nerve and on the medial side of the radial nerve.

The Profunda Artery arises from the brachial artery just below the Teres Major. It is the companion artery of the radial nerve. By its anastomoses it

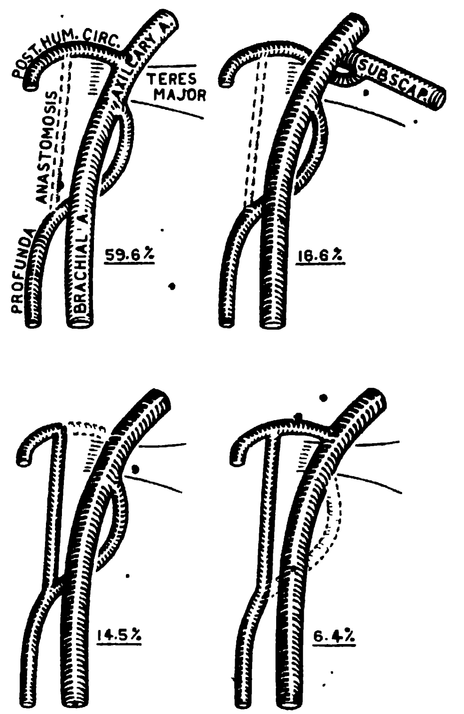


FIG. 105. Four types of variations in origin of the posterior humeral circumflex and profunda brachii arteries; in 2.9% the arteries were otherwise irregular. Percentages are based on 235 specimens.
In 7.3% of 123 specimens the profunda artery arose from the stem of the subscapular artery

brings the axillary artery above into communication with the radial and ulnar arteries below. Thus:

- Above, a *recurrent branch* (commonly present) ascends on the humerus between the Teres Major and lateral head of the Triceps and anastomoses with the posterior humeral circumflex artery.

Below, it has *two terminal branches*, an anterior and a posterior. The anterior branch follows the radial nerve "through"

the intermuscular septum and anastomoses with the radial recurrent artery; the posterior branch descends behind the septum to the back of the lateral epicondyle and anastomoses with the posterior interosseous recurrent artery (*fig. 185*).

A medullary or *nutrient branch* is commonly given off, in which case there is a foramen in the spiral groove. Obviously, there are also *muscular* and *cutaneous branches*. (*See fig. 105.*)

Features of Interest at Mid-arm. At the middle of the arm, where Coracobrachialis is inserted:

a. Basilic vein pierces deep fascia to become deep.

b. Medial cutaneous nerve of the forearm pierces the deep fascia to become cutaneous.

c. A subcutaneous lymph gland is not uncommonly present.

d. Median nerve crosses the brachial artery.

e. Ulnar nerve passes behind the intermuscular septum accompanied by the

f. Ulnar collateral artery and ulnar collateral nerve.

g. Medullary artery enters the bone.

CHAPTER 5

THE FLEXOR REGION OF THE FOREARM

You will find it profitable to construct the flexor region of the forearm by erecting the two bones as scaffolding and by building three layers of muscles on and around them. You must employ your knowledge of the palpable parts at the front of the elbow and wrist, for it will enable you without difficulty to install the nerves and vessels. If you can place them in correct relationship to the Flexor Digitorum Sublimis you will prove yourself master of the plan and you will hold the key of the region.

Deal with the structures in the following order: (a) The radius and ulna. (b) The muscles that immediately clothe them in front and medially. (c) The intermediately placed muscle – the Flexor Digitorum Sublimis. (d) The palpable structures at the wrist. (e) The superficial flexors. (f) The nerves and vessels.

The Radius and Ulna. The features of the ends of these two bones are to be identified now, and the flexor surfaces of the bodies studied in detail.

The proximal end of the **radius** consists of: *Head, neck,* and *radial tuberosity* for the Biceps insertion.

The distal end of the radius consists of: *Lower articular surface, ulnar notch, styloid process,* anterior and posterior aspects. On the last are the *dorsal radial tubercle of Lister* and several grooves.

The proximal end of the **ulna** consists of: *Olecranon, coronoid process, trochlear (semilunar) notch, radial notch,* and *ulnar tuberosity* for the Brachialis insertion.

The distal end of the ulna consists of: *Head, styloid process, pit* for the attachment of the articular disc, and *groove* for Ex. Carpi Ulnaris.

The *body of the radius* is cylindrical and somewhat tapering above; the *body of the ulna* is cylindrical and somewhat tapering below. The expanded lower two-thirds of the one and the expanded upper two-thirds of the other are triangular on cross section. The two bones are united by an *interosseous membrane,* which, on account of the disto-medial direction of its fibers is able to transfer from radius to ulna the force of an impact received by the hand (*fig. 106*). This strong membrane produces a rough ridge on the radius and an equally rough one on the ulna, known as their medial and lateral borders respectively, or alternatively as their *interosseous borders.*

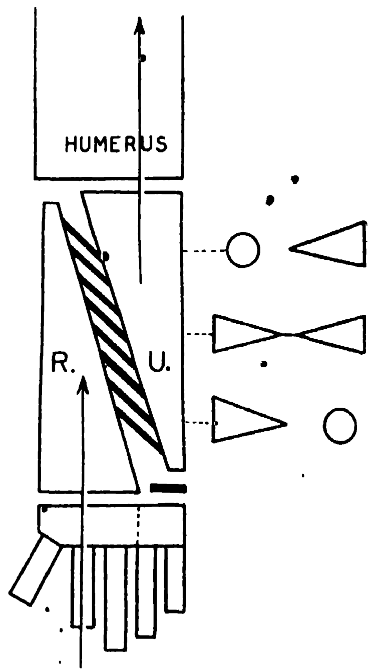


FIG. 106. Scheme of the radius and ulna.

The medial or interosseous border of the radius may be traced proximally, from where the two lines bounding the ulnar notch unite above a *triangular fossa*, to the radial tuberosity. The lateral or interosseous border of the ulna may be traced distally, from where the two lines bounding the radial notch unite below a convention is followed (*fig. 108*). **Therefore, as the radius has a medial border it must have a surface designated the lateral surface; and the ulna having a lateral border must have a surface designated the medial surface. Now, a glance at the skeleton will suffice to show that both the radius and the ulna have anterior and posterior surfaces and therefore as a corollary, posterior and anterior borders. Having no medial surface the radius cannot have a border**

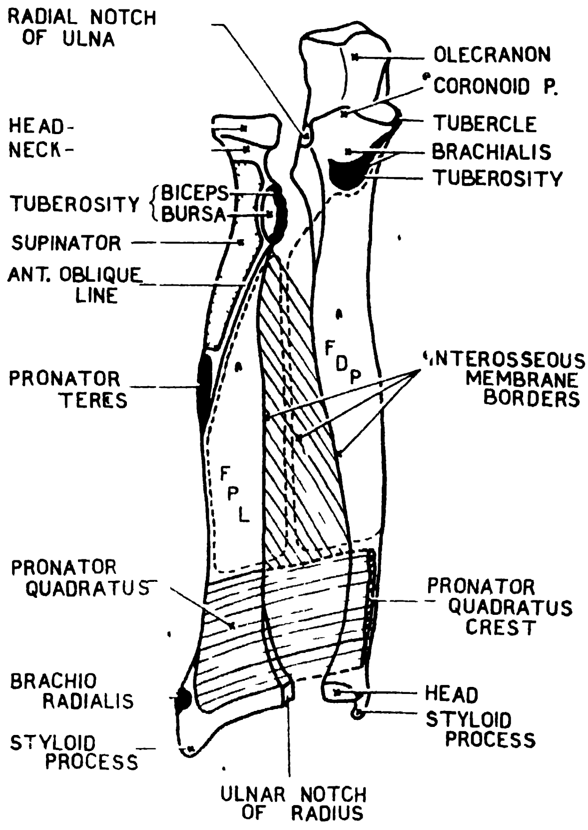


Fig. 107. Features of the radius and ulna (anterior aspect)

triangular fossa, to the lateral side of the head of the ulna (*fig 107*).

Conventions in Terminology. **Practically all long bones are triangular on cross-section, and their surfaces and borders are named by opposites. A surface diametrically opposite a medial border is logically named a lateral surface; and a surface opposite an anterior border is logically called a posterior surface; and, for other surfaces and borders this logical** **named the lateral; for a like reason the ulna cannot have a border named the medial. This is axiomatic; it is applicable to the names given to the surfaces and borders of all long bones —including the clavicle and the humerus. Because the borders and surfaces of the radius and ulna are outspoken and have considerable descriptive and practical value attention is directed to this matter of terminology now.**

It is well to reserve the term "*surface*" of a long bone for an area bounded by two specified

borders; and to apply the term "*aspect*" to an area visible from a certain aspect or viewpoint, and perhaps embracing two surfaces: for example, the lower half of the anterior aspect of the humerus includes its medial and lateral surfaces as well as the anterior border between them (*fig. 97*).

The body of the radius has:
Borders: medial, anterior, posterior.
Surfaces: lateral, posterior, anterior.

The body of the ulna has:
Borders: lateral, anterior, posterior.
Surfaces: medial, posterior, anterior.

At the summit of the convexity of the

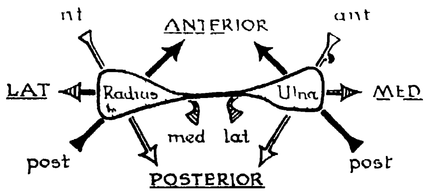


FIG. 108. Conventions in terminology illustrated by the radius and ulna on section: surfaces in large type; borders in small type.

lateral surface of the radius there is a rough *area for the Pronator Teres* This impression spreads right across the lateral surface; and from it two sharp lines, the *anterior* and *posterior oblique lines*, ascend across the anterior and posterior aspects of the bone to the radial tuberosity. These lines are the upper segments of the anterior and posterior borders respectively. They call to mind the deltoid tuberosity of the humerus and the proximal segments of the anterior and lateral borders of the humerus that ascend from it to the greater tuberosity (page 103). The entire V-shaped area of the body of the radius between the anterior and posterior oblique lines is appropriated by the *Supinator*. The anterior border can be traced downwards to the front of the styloid process; the posterior border to the dorsal radial tubercle of Lister (*fig. 148*).

The posterior border of the ulna extends from the apex of the posterior *subcutaneous surface of the olecranon*, on which lies the olecranon bursa, to the back of the styloid process. This border is sharp, subcutaneous, and always palpable from end to end; and when the forearm is raised in self-protection, it is liable to be struck and the bone fractured.

The anterior border extends from the tuberosity on the coronoid process, into which the Brachialis is inserted, to the front of the styloid process. It is smooth, except in its lower quarter where it forms a rough ridge, the *pronator ridge*, for

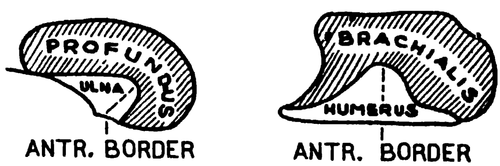


FIG 109. The rounded anterior borders of the humerus and ulna acting as strengthening bars (see also fig. 86)

the fibrous origin of the Pronator Quadratus. The smooth, rounded, anterior border of the ulna separates the anterior and medial surfaces. It is a strengthening bar that fulfils the same function as the smooth, rounded, anterior border of the humerus (*fig. 109*). The former gives origin to fleshy fibers of the Flexor Digitorum Profundus; the latter to fleshy fibers of the Brachialis. Functionally and morphologically, then, the medial surface of the ulna belongs to the flexor surface of the forearm. The posterior and lateral borders afford attachment to fibrous tissue and owe their sharp and rough qualities respectively to this fact.

Boundaries. The flexor region of the forearm has as its basis the anterior surface of the radius and the anterior

and medial surfaces of the ulna (*fig. 110*). Medially, it is marked off from the extensor region by the olecranon and the posterior border of the ulna, both of which are subcutaneous. Laterally, it is marked off from the extensor region by the anterior border of the radius, which is submerged except near the wrist.

Guarding the lateral boundary like 4 sentinels are the sites of insertion of the tendons of the 4 flexors of the elbow join—Brachialis, Biceps, Pronator Teres, Brachio-radialis (*fig. 111*). More superficially the course of the radial artery serves as a practical guide to the lateral boundary.

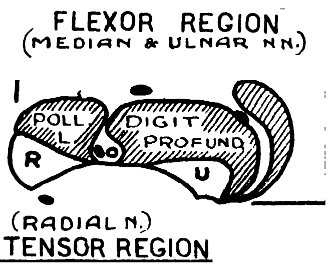


FIG. 110. Regions of the forearm.

Muscles That Clothe the Flexor Aspects of the Bones. The *Pronator Quadratus* arises from the pronator ridge of the ulna and from the anterior surface of the bone lateral to it. It is inserted by fleshy fibers into the smooth, lower quarter of the anterior surface of the radius as well as into the triangular area above the ulnar notch. This is possible because the interosseous membrane follows the hinder of the lines limiting this triangular area. The *Flexor Pollicis Longus* arises from the smooth, anterior surface of the radius and adjacent part of the interosseous membrane from the level of the Pronator Quadratus below right up to the anterior oblique line from which the aponeurotic radial head of the *Flexor Digitorum Sublimis* arises. Above this level the *Supinator* has been seen to occupy the bone up to and beyond the insertion of the *Biceps* into the posterior, rough half of the radial tuberosity. The *Flexor Digitorum Profundus* arises from the smooth anterior surface, smooth rounded anterior border, and smooth medial surface of the ulna, from the level of the Pronator

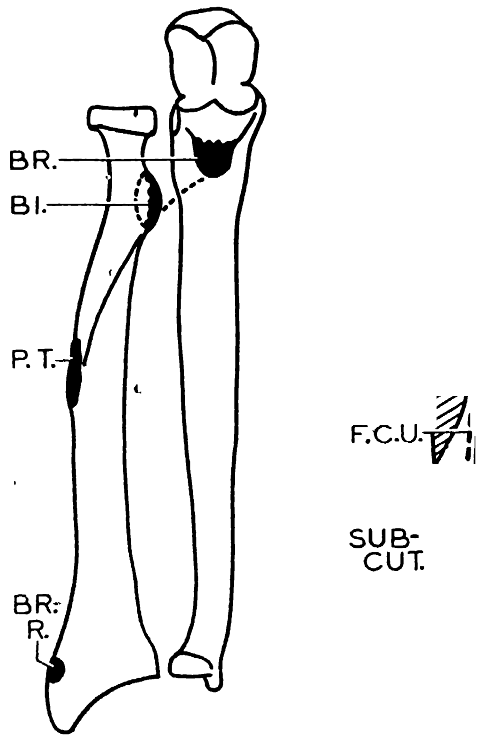


FIG. 111. Flexor aspect of the bones of the forearm. The four flexors of the elbow like sentinels guard the boundary between flexor and extensor territories.

Quadratus right up to the insertion of the *Brachialis* anteriorly and up so as to cover the coronoid process and olecranon medially.

Note that, between them, the seven foregoing muscles occupy all the available space on the anterior aspects[4] of

[4] The anterior *aspect* of radius includes the entire anterior surface, the anterior oblique line, and part of the lateral surface for the Supinator, and radial tuberosity. The medial *aspect* of ulna includes the medial surface, and the medial surfaces of the coronoid process and olecranon.

the bodies of the radius and ulna as well as on the medial aspect of the ulna above its lower one-third, which is subcutaneous. They may be thought of as a carpet. The vessels and nerves that pass through the flexor region of the forearm are separated from the bones by this carpet; that is to say, they pass progressively from one muscle to another without touching bone. This statement is wholly true of the ulnar artery and nerve, and of the median nerve. It is true of the radial artery, except at its lower part where the pulse is felt. Reservations, however, must be made regarding the anterior interosseous artery and nerve.

Axioms. (a) Since the individual fleshy fibers of the deep digital flexors (i.e., Flexores Pollicis Longus and Digitorum Profundus) are of approximately the same length, it must follow that their tendons begin on their anterior aspects (*fig. 112*).

(b) The fleshy fibers must cease before the projecting anterior border of the lower end of the radius (or ulna) is reached, because fleshy fibers cannot survive severe pressure or friction.

(c) Even a tendon at such a site of friction requires a bursa or synovial sheath to facilitate its play.

Observe that the Pronator Quadratus is sheltered by the projecting anterior border of the lower end of the radius, and that the deep flexors bridge it and therefore do not hamper its action.

(d) It is self evident that the sectional area of the tendon of a muscle is smaller than the sectional area of its fleshy belly. This being so, the tendons of the deep digital flexors are able to converge on the mid line of the limb in order to enter the carpal tunnel (*fig. 131*). In doing so, the tendon of the Flexor Pollicis Longus must leave the lateral part of the Pronator Quadratus uncovered, thereby allowing the radial artery to come to lie on it (*fig. 113*); and, the Flexor Digitorum Profundus must leave the lower third of the medial surface of the ulna denuded, and, therefore, subcutaneous and palpable between the tendons of the Flexor and the Extensor Carpi Ulnaris (*fig. 111*).

The five tendons of the deep digital flexors lie side by side as they pass through the carpal tunnel. In lower primates there is a common deep digital flexor for the five digits, but in man the Flexor Pollicis Longus is an independent muscle and the deep tendon to the index acquires a certain independence in the forearm.

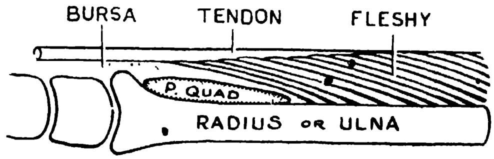


FIG. 112. Tendon of deep digital flexor: for axioms see text.

The Anterior Interosseous Nerve and Artery arise from the median nerve and common interosseous artery respectively an inch or so below the elbow, and pass to the interosseous membrane. Thereafter, the nerve and artery and their branches cling to, and never part from, the "skeletal plane".

By *Skeletal Plane* is meant: bone, interosseous membrane, ligament, or joint capsule.

The Nerve supplies the three deep muscles (Fl. Pollicis Longus, Fl. Digitorum Profundus, and Pronator Quadratus); but not entirely: the branches it sends to the deep flexors control the tendons to the 1st, 2nd, and 3rd digits, leaving those to the 4th and 5th for the ulnar nerve to supply. This it does a little below the elbow. The Flexor Digitorum Profundus has, then, a double nerve supply. The anterior interosseous

nerve ends by supplying the wrist and carpal joints.

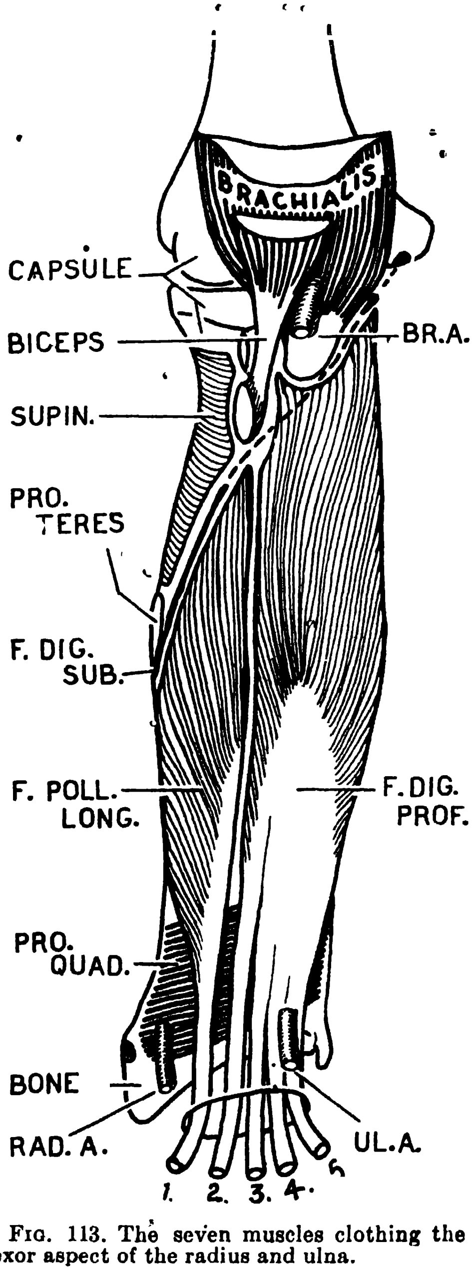


Fig. 113. The seven muscles clothing the flexor aspect of the radius and ulna.

The Artery supplies a medullary branch to the radius and one to the ulna, and ends by anastomosing on the front and back of the wrist. Primitively, it was the direct continuation of the brachial artery, and in prenatal life it was for a period the only artery in the forearm; so, it is of historical interest.

The Flexor Digitorum Sublimis (*fig. 114*) occupies an intermediate position

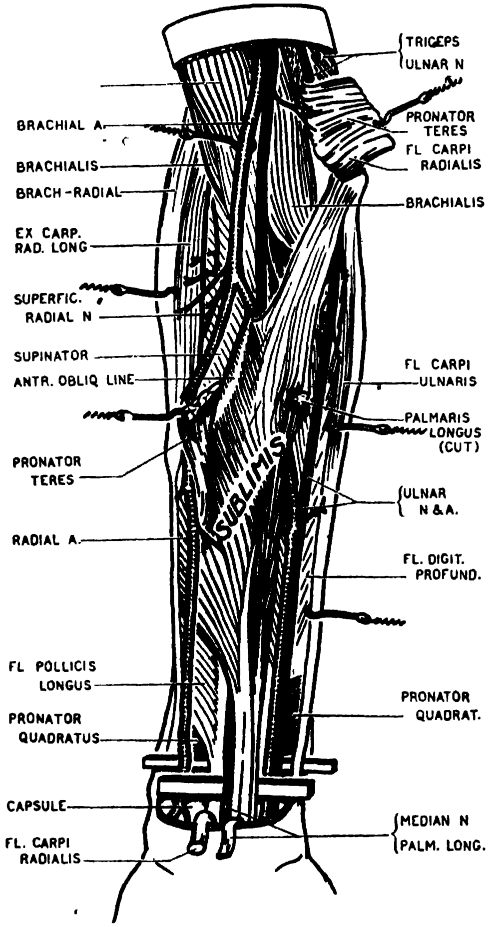


Fig. 114. The key position of the Flexor Digitorum Sublimis with reference to the nerves and arteries.

between the superficial and deep flexors. Developmentally, it is a delaminated portion of the deep flexors of the digits; and, it arises at their upper borders (*fig. 113*). Thus, it arises from: (1) the anterior oblique line of the radius between the attachments of the Flexor Pollicis Longus

and the Supinator; (2) the anterior strong fibrous cord of the medial ligament (ulnar collateral lig.) of the elbow joint, and from the bone at each end of the ligament, (viz., the medial epicondyle of the humerus and the tubercle on the coronoid process of the ulna); (3) the intermuscular septa, especially the septum between it and the Fl. Carpi Ulnaris. It has, then, a humeral, an ulnar, and a radial origin.

A fibrous band bridges the interval between the ulnar and radial origins and thereby allows the median nerve and ulnar artery to pass deep to the Flexor Digitorum Sublimis.

Unlike the tendons of the Fl. Digitorum Profundus which lie side by side, the tendons of the Fl. Digitorum Sublimis are "two deep", those for digits 3 and 4 being in front of those for digits 2 and 5; and all four are free in the forearm. The radial head belongs to digit 3; the fleshy bellies for digits 2 and 5 are interrupted about their middles by intermediate tendons; that is to say, they are digastric muscles.

The median nerve supplies the Sublimis, including the proximal and distal bellies of the digastric parts, and it clings closely to its deep surface.

Intermuscular Lines. Note (a) that when a finger or the handle of an instrument is insinuated from the lateral side of the forearm in front of the Fl. Pollicis Longus and carried proximally, it is arrested by the attachment of the Flexor Digitorum Sublimis to the anterior oblique line of the radius; (b) that when insinuated from the medial side in front of the Flexor Digitorum Profundus and carried proximally, it is arrested by the attachment of the Flexor Carpi Ulnaris to the posterior border of the ulna; (c) that when insinuated between the Flexor Carpi Ulnaris and Flexor Digitorum Sublimis and carried proximally, it is arrested by the common septum from which these two muscles spring. Now, the Flexor Digitorum Sublimis is supplied by the median nerve and the Flexor Carpi Ulnaris by the ulnar nerve; so, the septum marks an *internervous line.* This may safely be opened up, the two muscles pulled apart, and access gained to the

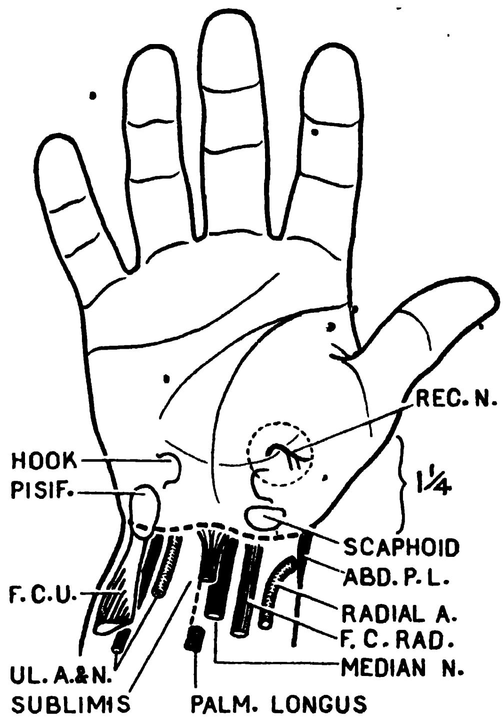


Fig. 115. Surface anatomy of the front of the wrist: a key position.

deeper parts of the forearm without fear of damaging a motor nerve, until a point is reached about $2\frac{1}{2}''$ below the medial epicondyle, for at this level branches of the ulnar nerve enter the Flexor Digitorum Profundus and Flexor Carpi Ulnaris.

Surface Anatomy of the Front of the Wrist (*fig. 115*). **The relations of the structures at the front of the wrist must be established as part of your present**

knowledge. Like the structures about the elbow, they must be identified by palpation in the living subject and confirmed by dissection. They occupy the 3rd key position on the front of the limb.

The most distal *skin crease* at the wrist, slightly convex towards the palm, corresponds to the upper border of the flexor retinaculum (transverse carpal ligament). It crosses the two prominent proximal bony pillars to which the retinaculum is attached, namely: the *tubercle of the scaphoid bone* laterally, the *pisiform bone* medially. Where the prominent tendon of the *Flexor Carpi Radialis* crosses this skin crease at the junction of its lateral one-third with its medial two-thirds, it passes in front of the scaphoid tubercle and so serves as a guide to it. The Flexor Carpi Radialis is rendered very prominent when the clenched fist is fully flexed and abducted against resistance. The tendon of the *Flexor Carpi Ulnaris*, the most medial of all the structures at the wrist, can be traced to the pisiform at the medial end of the crease. The most lateral of all the structures are the tendons of the *Abductor Pollicis Longus* and *Extensor Pollicis Brevis*. Bisecting the distal skin crease, (i.e., at the middle of the front of the wrist,) is the most important of all the structures—the *median nerve*. It cannot be palpated, but it is there. Two layers of fascia and the *Palmaris Longus* tendon lie in front of it. The Palmaris Longus is to be brought into prominence by fully flexing the closed fist and then applying resistance to it. [In a series of 224 subjects, Palmaris Longus was present on both sides in 80%, absent on both sides in 8%, absent on the right only in 7% and absent on the left only in 5%, R. K. George.] The *radial artery* is to be felt pulsating between the Fl. Carpi Radialis and the Abductor Pollicis Longus. The *ulnar artery* and *nerve* pass into the palm immediately lateral to the pisiform. As, however, a strong band of fascia covers them, the pulse of this artery is not easily felt. Finally, when the wrist is extended, a fulness, due to the *Flexor Digitorum Sublimis*, appears between the Flexor Carpi Ulnaris and the Palmaris Longus. The *lower end of the radius* can be grasped between the fingers and thumb. The anterior margin of its articular surface is surprisingly prominent and rugged.

The Four Superficial Flexors are the Pronator Teres, Flexor Carpi Radialis, Palmaris Longus, and Flexor Carpi Ulnaris (*fig. 116*). They have a common and, therefore, a fibrous origin from the front of the medial epicondyle of the humerus, from the investing deep fascia, and from the septa between adjacent muscles. The *Pronator Teres*, being the most lateral, is able by fleshy fibers to creep upwards towards the shaft of the humerus. The *Flexor Carpi Ulnaris*, being the most medial, is able to bridge the ulnar nerve and to creep along the medial border of the olecranon and down the sharp posterior border of the ulna. This ulnar head, being attached to a sharp border, is of course aponeurotic. It cannot creep further than $\frac{3}{4}$ of the way down this border because its tendon of insertion has to reach the pisiform bone; so, it repeats the procedure of the Flexor Digitorum Profundus, and thereby leaves the lower $\frac{1}{4}$ of the medial surface of the ulna denuded and subcutaneous (*fig. 111*).

The four superficial muscles spread out fanwise in an obvious sequence, and the tendons of all but the Pronator Teres have been recognized at the wrist. In order that the *Pronator Teres* may pronate, it creeps on to the lateral surface

of the radius, thereby invading extensor territory. It is inserted into the whole breadth of the lateral surface of the radius at its middle, and being fibrous it

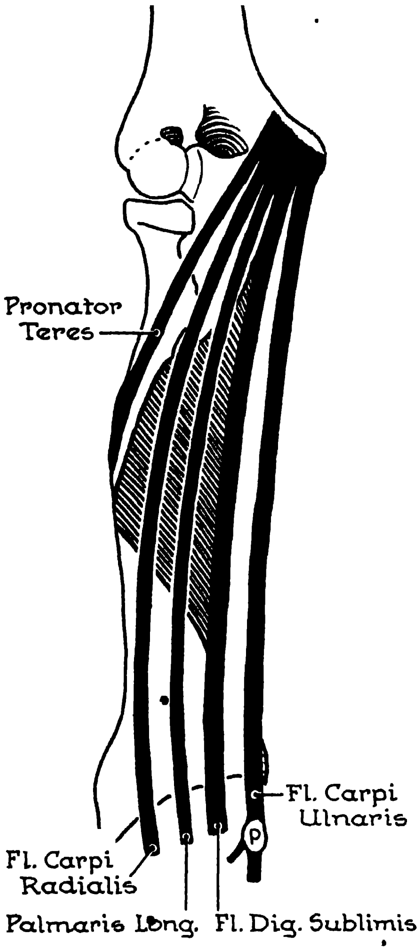


FIG. 116. The four superficial flexors and the intermediately placed muscle (Flexor Digitorum Sublimis).

leaves a mark. It cannot be identified by palpation.

The Arteries and Nerves of the Front of the Forearm. Familiar with the surface anatomy of the structures at the elbow, and familiar with the surface anatomy of the structures at the wrist, you cannot find it difficult to map out the general courses of the:

Ulnar artery and nerve.
Radial artery and nerve.
Median (artery and) nerve.

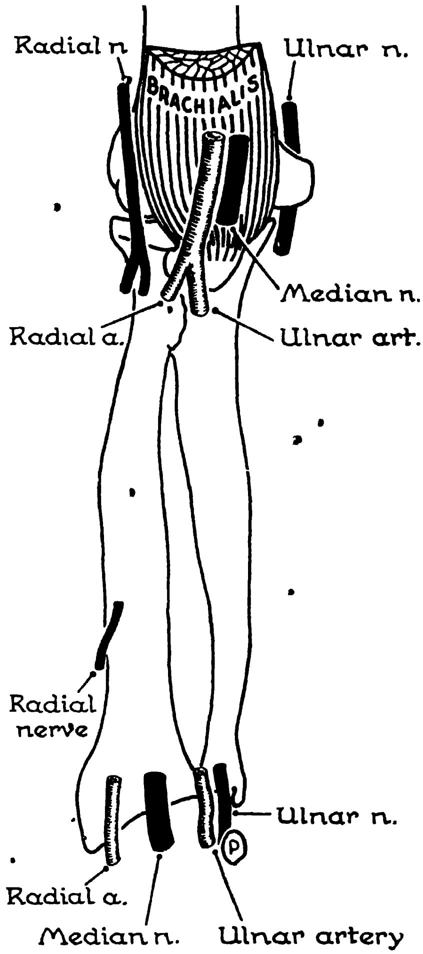


FIG. 117. The vessels and nerves of the forearm at the key positions

You can postulate (a) that the vessels and nerves cross superficial to the muscles that carpet the radius and ulna; (b) that the ulnar and (superficial) radial nerves together embrace their companion arteries (*fig. 117*); (c) that the median nerve crosses the ulnar artery; (d) that the median nerve and ulnar artery pass

under the "Sublimis arch" which is specially designed for their passage; and (e) that the ulnar nerve passes under the bridge between the humeral and ulnar heads of the Fl. Carpi Ulnaris.

Surface Anatomy. Slightly curved lines, connecting the site where the brachial artery was observed to divide to the points where the ulnar and radial arteries were identified at the wrist, indicate the general directions of the two arteries.

The Ulnar Artery. In its course, this artery obviously passes either superficial or deep to the Pronator Teres, Fl. Carpi Radialis, Palmaris Longus, and Fl. Digitorum Sublimis, in order to come under the shelter of the Fl. Carpi Ulnaris. The question is which does it do. Naturally, it passes deep to the fibrous arch that connects the radial and humero-ulnar heads of the Fl. Digitorum Sublimis, because this is the purpose of the arch; therefore it passes deep also to the superficial flexors. Behind this arch the median nerve crosses the ulnar artery from medial to lateral side, and it crosses superficially, (the deep head of the Pronator Teres intervening). Behind the ulnar artery are the muscles clothing the anterior aspect of the ulna, namely: the Brachialis and the Fl. Digitorum Profundus. The Pronator Quadratus is not an immediate posterior relation (*fig. 113*).

Its pulse is not readily felt at the wrist because it is there bridged by a taut band of deep fascia, the *volar carpal lig.*, which stretches from the Fl. Carpi-Ulnaris to the trapezium (*fig. 133*).

THE BRANCHES of the ULNAR ARTERY:

1, 2. *Anterior and posterior ulnar recurrent aa.* take part in the anastomoses around the medial epicondyle, the posterior artery following the ulnar nerve proximally (*fig. 185*).

3. *Common interosseous a.* is a short stem that passes to the upper border of the interosseous membrane and divides there into the anterior and posterior interosseous aa. Their branches are:—

Anterior interosseous artery:
- Median, companion of the median nerve.
- Medullary, to radius and ulna.
- Muscular.
- Anterior communicating, anastomoses in front of the wrist.
- Terminal, anastomoses behind the wrist (*fig. 143*).

Posterior interosseous artery:
- Recurrent, anastomoses behind the lateral epicondyle.
- Muscular.
- Terminal, anastomoses behind wrist.

4. *Muscular branches.*

5, 6. *Anterior and posterior ulnar carpal aa.* take part in the anastomoses around the wrist (*fig. 143*).

The *median artery* is of historical and practical interest. For a brief period in embryonic life it is the lineal successor to the anterior interosseous artery and, as the chief artery of the forearm and hand, it accompanies the median nerve through the carpal tunnel into the palm where it supplies certain digits until it disappears. Occasionally it persists.

The Radial Artery. If in a dissected limb the muscular branches of the radial artery are severed, the vessel can be lifted right up from its bed, because like its parent, the brachial artery, it is not crossed by any muscle. To impress this fact, lift up the brachial and radial arteries, noting, (a) that if the bicipital aponeurosis is cut, no muscle is found to cross or bind down either artery; and (b) that the median nerve is the only important structure to cross superficial to either vessel. Why then can the radial pulse not be felt throughout the

entire course of the artery? Because the Brachio-radialis overlaps it.

The radial artery lies between the extensor and flexor groups of muscles. The Brachio-radialis is lateral and overlaps it; the Pronator Teres is medial in its upper one-third; the Flexor Carpi Radialis is medial in its lower two-thirds. Immediately behind it are the muscles that clothe the anterior aspect of the radius (*fig. 113*), namely, the Biceps, Supinator, Pronator Teres, radial head of the Fl. Sublimis, Fl. Pollicis Longus, Pronator Quadratus, and beyond these the lower end of the radius and the capsule of the wrist joint. They occur in the sequence just given.

The artery gains the back of the wrist by passing below the styloid process and deep to the Abductor Pollicis Longus.

The (superficial) radial nerve accompanies the artery in the middle third of the forearm.

THE BRANCHES given off by the radial artery in the forearm are:

1. *Muscular.*

2. *Recurrent,* anastomoses in front of lateral epicondyle and follows the radial nerve proximally.

3. *Anterior carpal* (p. 158).

4. *Superficial palmar,* arises at the wrist and enters the thenar muscles. It commonly completes the s. palmar arch. When large its pulsations can be felt.

The Ulnar Nerve takes a straight course from the back of the medial epicondyle to the lateral side of the pisiform. It lies throughout on the Fl. Digitorum Profundus. The Fl. Carpi Ulnaris covers it proximally and overlaps it distally. Its artery approaches it, obviously from the lateral side, and is in contact with it in the lower two-thirds of its course.

Branches (*fig. 158*). At the elbow the ulnar nerve supplies 1½ muscles, namely: the Fl. Carpi Ulnaris and the medial half of the Fl. Digitorum Profundus—These are the only muscles it supplies above the level of the wrist—and it sends twigs to the elbow joint. Somewhat above the wrist its palmar and dorsal cutaneous branches arise (*fig. 92*).

If you sever the humeral origin of the Fl. Carpi Ulnaris, you can bring the ulnar nerve to the front of the elbow; and if you then flex the elbow joint, you shorten the course of the nerve by several inches.

The (Superficial) Radial Nerve, or portion of the radial nerve distal to the origin of the posterior interosseous nerve, is the last cutaneous branch of the radial nerve. To expose it, turn the Brachio-radialis laterally.

After crossing the capsule of the elbow joint, the nerve descends along the anterior border of the Ex. Carpi Radialis Longus and crosses the muscles that clothe the radius (viz., Supinator, Pronator Teres, Fl. Digitorum Sublimis, and Fl. Pollicis Longus). It then passes backwards between the Brachio-radialis and Ex. Carpi Radialis Longus and becomes cutaneous about 2″ above the styloid process of the radius. The radial artery approaches the nerve from the medial side and accompanies it through the middle third of the forearm.

The Median Nerve. You have palpated it medial to the brachial artery at the elbow and you have located it where the Palmaris overlaps it at the midpoint of the wrist. It takes a straight course between these two points. It passes with the ulnar artery deep to the "Sublimis bridge" and therefore deep to four muscles (i.e., Pronator Teres, Fl. Carpi Radialis, Fl. Digitorum Sublimis, and Palmaris Longus). It happens to cross superficial to the ulnar artery, (the slender deep head of the Pronator

Teres intervening). Behind it are the muscles clothing the front of the ulna, namely, the Brachialis and Fl. Digitorum Profundus.

Branches (*fig. 158*). The median nerve supplies all the flexor muscles of the forearm, except the $1\frac{1}{2}$ supplied by the ulnar nerve. The branches to four of these, namely, the Pronator Teres, Flexor Carpi Radialis, Palmaris Longus, and Fl. Digitorum Sublimis, spring from the main stem, obviously from its medial side. They commonly arise above the level of the elbow.

Its obligations to the $2\frac{1}{2}$ deep muscles being discharged by its interosseous branch, the median nerve is free to adhere to the deep surface of the Fl. Digitorum Sublimis and to give it branches in its course through the forearm.

The median nerve is accompanied by the median artery, which, though usually mere twig, may be a large vessel.

THE HAND

The Bones and Joints of the Hand. There is little purpose in studying the bones of the hand individually before you are familiar with them collectively, so, we shall consider first the hand as a whole, and later attend to the notable features of the individual bones. And, because considerable areas of the different bones take parts in joints, we should find it difficult and unnecessary to avoid discussing the joints and ligaments with the bones.

When reading the following remarks have beside you the bones of the hand, preferably strung on catgut. Do not omit also to make the suggested observations on your own hand.

The following comprise the skeleton of the hand:

a. The carpal bones, or bones of the wrist.

b. The metacarpal bones, or bones of the hand proper.

c. The phalanges, or bones of the digits.

The digits are numbered I, II, III, IV, V. The first digit is the thumb or pollex; the second, the forefinger or index; the third, the middle finger or digitus medius; the fourth, the ring finger or digitus annularis; and the fifth is the little finger, or digitus quintus, or digitus minimus.

The Carpal Bones are short or cubical bones (p. 0). The only other cubical bones in the body are the tarsal bones. The metacarpals and phalanges are long or cylindrical bones. Being cubical, the carpal bones have typically six surfaces. Of these, two surfaces, the *anterior* and *posterior*, are rough for the attachment of ligaments, while four surfaces articulate with adjacent bones and are, therefore, covered with cartilage. Obviously, the lateral surfaces of the lateral bones and the medial surfaces of the medial bones, otherwise known as the *marginal surfaces*, are not articular, but are rough for ligaments.

Cubical or short bones resemble the pressure epiphyses of long bones: (a) in structure—both being composed of cancellous tissue, which is completely encased within a shell of compact bone, which in turn is covered in part with hyaline cartilage, (b) in retaining red marrow for some years after it has disappeared from the bodies of long bones, and (c) in not starting to ossify until shortly before birth or within a few years after it.

The carpal bones, eight in number, are arranged in a proximal and a distal row, each of four bones. Their names express their general appearance. From radial to ulnar side they are:

Proximal row—*scaphoid, lunate, triquetrum,* and *pisiform.*

Distal row—*trapezium, trapezoid, capitate,* and *hamate.*

(B.N.A. scaphoid = navicular; trapezium = greater multangular; trapezoid = lesser multangular.)

It may be helpful first to picture these as eight uniform cubes arranged as in figure *118,* and then to modify this diagram as investigation of your own hand and of the skeleton proceeds.

THE PROXIMAL SURFACE OF THE CARPUS. The general disposition of the bones is shown better in figure 119 in which three essential alterations have been made: (a) the pisiform has been placed in front of the triquetrum, leaving three bones only of the proximal row in articulation with the radius and the articular disc. (b) The scaphoid has been widened to support two of the distal bones, *trapezium* and *trapezoid,* leaving one each for the lunate and triquetrum. (c) The upper surface of the proximal row is shown not as a plane gliding surface, but as an ovoid surface, convex both from side to side and from before backwards. The superior and lateral surfaces of the scaphoid, therefore, merge into one rounded surface; and the superior and medial surfaces of the triquetrum merge similarly into one rounded surface. It is in consequence of this, observe, that you can abduct and adduct your wrist joint, and also flex and extend it.

THE DISTAL SURFACE OF THE CARPUS AND THE PROXIMAL SURFACES OF THE BASES OF THE METACARPALS. Neither is this a plane gliding surface, such as would allow the metacarpals to shift from side to side, and backwards and forwards. It is very irregular (*fig. 120*), and the irregularities are now to be accounted for. The metacarpal bones of the five digits (thumb and four fingers) have only four carpal bones with which to articulate. The articulated hand reveals that the bases of the 4th and 5th metacarpals articulate with the hamate. [In

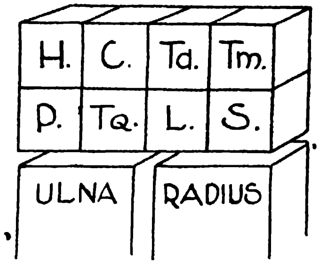


FIG. 118. The carpal bones as cubes.

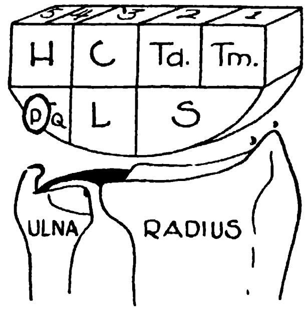


FIG. 119. The carpal cubes modified.

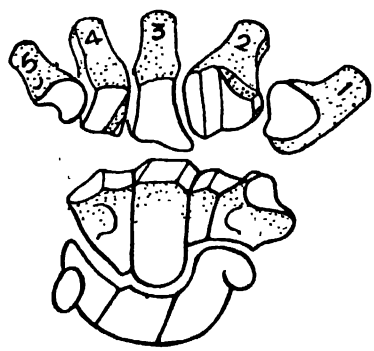


FIG. 120. The carpal bones and the bases of the metacarpal bones.

the turtle the hamate like its homologue in the foot, the *cuboid,* is represented by two bones.] Grasp in turn the knuckles or heads of the metacarpals of your own fingers, noting that the 5th metacarpal can be moved freely backwards and

forwards, that the 4th metacarpal can be moved to a lesser degree, and that the 3rd and 2nd metacarpals are immobile. Again, view the back of your knuckles as you tightly close your fist and you will see illustrated the same fact: that the 5th and 4th metacarpals flex at their carpo-metacarpal joints while the 3rd and 2nd remain rigid and immobile. An examination of the carpus gives the reason: the 5th and 4th carpo-metacarpal joints are clearly hinge joints, the hamate presenting two concavities for the convex bases of the 5th and 4th metacarpals. [In the foot the corresponding articular surfaces of the cuboid for the 5th and 4th metatarsals are similarly fashioned.] The capitate has an expansive plane surface for the base of the 3rd metacarpal. The trapezoid (lesser multangular) does not project so far distally as the carpals on each side of it; and in consequence, the base of the 2nd metacarpal is morticed between the capitate and trapezium (greater multangular), and in part articulates with them. The trapezoid, moreover, possesses an antero-posteriorly placed ridge which fits like a wedge into the guttered base of the 2nd metacarpal. Although the metacarpal of the thumb or pollex can be flexed and extended, abducted and adducted, and rotated, it does not possess the spherical base you naturally look for, but a saddle-shaped surface which fits on to the distal surface of the trapezium, which is reciprocally saddle-shaped. To allow of these free movements the capsule around the carpo-metacarpal joint of the thumb must necessarily be slack.

The distal surface of the carpal mass is, therefore, not a plane surface, but an irregular one. With such is associated limitation of movement. The morticing of the metacarpal of the index effectively prevents side to side shifting of the metacarpals and contributes largely to the stability of the carpo-metacarpal joints.

It is instructive to note that the 2nd metacarpal articulates with three carpals, and that the stalwart capitate articulates with three metacarpals (*fig. 121*). The three facets on the base of the capitate are: a broad surface for the 3rd metacarpal, a long narrow strip placed laterally for the 2nd, and a small facet placed postero-medially for the 4th.

DORSAL AND PALMAR ASPECTS OF THE CARPUS. Observe that the dorsum of your wrist is transversely arched or convex, and that the dorsum of an

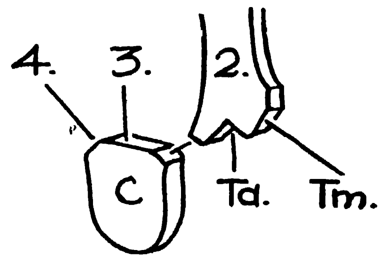


FIG 121. The capitate articulates with three metacarpals: The 2nd metacarpal articulates with three carpals.

articulated carpus likewise is transversely arched or convex. Its palmar surface is hollow or concave. The arched condition is maintained by a tie-beam, the *flexor retinaculum* (transverse carpal ligament), which unites the marginal bones of the carpus. Its proximal part extends between two rounded prominences, namely, the *pisiform* and the *tubercle of the scaphoid* (*figs. 131, 132*). Its distal part stretches between two crests, namely, the *hook of the hamate* and the *ridge of the trapezium* These crests, being the ossified ends of the distal half of the tie-beam, are directed towards each other. The ridge of the trapezium is also the lateral lip of a groove in which the tendon of the Flexor Carpi Radialis runs on its way to the base of the second (and third)

metacarpal, where it is inserted. The groove is, therefore, placed vertically; and at its upper end is the prominent tubercle of the scaphoid which acts as a pulley over which the tendon plays.

Like the stones in an arch of masonry the carpal bones are broad on their convex or dorsal aspects, and narrower on their concave or palmar aspects, with the single exception of the lunate which is more expansive ventrally than dorsally. When the lunate becomes dislocated or dislodged, the displacement tends to be forwards. The trapezoid makes a very slight appearance on the front of the carpus.

Palpable Parts. The lowest transverse skin crease at the front of the wrist has been seen to cross the pisiform and the tubercle of the scaphoid. The Flexor Carpi Ulnaris has been traced to the pisiform, and the Flexor Carpi Radialis to the tubercle of the scaphoid. The hook of the hamate can be palpated as a resistant structure infero-lateral to the pisiform, the interval between them being sufficient to allow of the passage of the ulnar artery and nerve (*fig. 131*). Immediately below the tubercle of the scaphoid lie the groove and ridge of the trapezium. The ridge can be identified by its resistant feel. The scaphoid and the trapezium can also be palpated in the "*anatomical snuff-box*", that is, the hollow at the lateral side of the wrist between the styloid process of the radius proximally and the base of the metacarpal of the pollex distally. Here the radial artery crosses them, and its pulse can be felt on employing light pressure.

Joint Surfaces. When you close your fist or grasp an object, your wrist automatically becomes extended, that is, dorsiflexed. Dorsi-flexion at the radio-carpal joint is more free than palmar flexion, therefore the articular cartilage covering the upper surfaces of the scaphoid, lunate, and triquetral bones extends far dorsally.

THE MIDCARPAL OR TRANSVERSE CARPAL JOINT lies between the proximal and distal rows of carpal bones (*fig. 120*). Here the trapezium and trapezoid together form a *small lateral unit* which presents a concave, oval surface for articulation with the convex, oval inferior surface of the scaphoid. The capitate and hamate together form a *large medial unit*, whose combined upper surfaces form a sphere or ball which articulates with the concave socket formed by the scaphoid, lunate, and triquetrum. The transverse or midcarpal joint therefore is sinuous. At it the greater part of the flexion, which appears to take place at the radio-carpal joint, in reality takes place.

When you touch the back of your right shoulder with the tips of your right digits, you may be said to wind up your limb, by flexing the following joints: shoulder, elbow, radio-carpal, midcarpal, 1st, 4th, and 5th carpo-metacarpal (the 2nd and 3rd are immobile), metacarpophalangeal, and interphalangeal. One bony surface of each of these joints is necessarily concave; the other is convex.

Striking a Blow. You may crystallize your knowledge of the carpals by considering the mechanism involved in striking a blow. When you strike a blow with your fist, you instinctively employ the knuckles of the 2nd and 3rd metacarpals in preference to those of the 4th and 5th. Why is this? Because, (a) The 2nd and 3rd metacarpals are long, stout, and strong; whereas the 4th and 5th are shorter and more slender. (b) The bases of the 2nd and 3rd are individually equal in surface area to the combined bases of the 4th and 5th. (c) The 2nd and 3rd are rigid and immobile; whereas the 4th and 5th are not.

(d) The line of force travelling along the 2nd and 3rd metacarpals is transmitted directly to the radius via the trapezoid and scaphoid, and via the capitate and lunate (*fig. 122, 123*); whereas that travelling along the 4th and 5th is transmitted via the apex of the hamate to a linear facet on the lunate and so to the radius. Further, (e) The upper articular facet of the triquetrum, such as it is (*fig. 131*), is

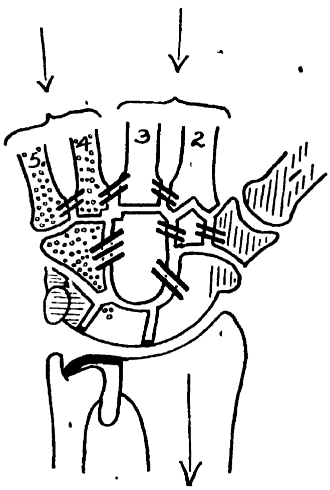


FIG. 122. When striking a blow use the 2nd and 3rd knuckles. Observe that the ligaments take the directions of usefulness

applied to the medial (ulnar collateral) ligament of the wrist, except during adduction of the wrist when it moves into contact with the articular disc of the radio-carpal joint; so, the triquetrum and pisiform are not force transmitters.

Ligaments. On striking with the 4th and 5th knuckles, the direction taken by the strong interosseous ligaments uniting the 4th to the 3rd metacarpal, and the hamate to the capitate, is such as to relieve the linear facet on the lunate of the brunt of the impact. And the small facet on the capitate for the 4th metacarpal takes some of the impact directly.

Intercarpal Ligaments. The various carpal bones are bound to each other by dorsal and palmar bands which largely radiate from the capitate. The bones of the proximal row are further united to each other by interosseous bands which shut off the radio-carpal joint from the intercarpal joints. The bones of the distal row are united to each other by incomplete interosseous ligaments, of which the one between the hamate and capitate is very strong. No interosseous bands exist to hamper the movements between proximal and distal rows, where flexion is so surprisingly free. Between the individual bones of each row a slight amount of gliding can take place; that is to say, the joints are plane (arthrodial).

Muscles. No muscle is inserted into any carpal bone. All muscles that cross the radio-carpal joint also cross the mid-carpal and carpo-metacarpal joints, that is to say, they span the carpus, gain insertion to the metacarpals and phalanges, and control the joints they cross. Three short muscles of the thumb and three of the little finger, however, arise from the flexor retinaculum (transverse carpal ligament) and from the four marginal bones it unites.

When saying no muscle is inserted into any carpal bone, one is regarding the pisiform as a *sesamoid bone* developed in the tendon of the Fl. Carpi Ulnaris and as being to the Fl. Carpi Ulnaris what the patella is to the Quadriceps Femoris. The pisometacarpal ligament, which passes from pisiform to the base of the fifth metacarpal would represent the lig. patellae (*fig. 133 and page 147*).

The Metacarpal Bones are long bones, each having a body and two ends.

The Proximal Ends or Bases of the Metacarpals have articular facets which are counterparts of the distal surfaces of the carpals (*fig. 120*). They have been

described. You will remember that the second metacarpal articulates with three carpals—the trapezium, trapezoid, and capitate; and that the capitate articulates with three metacarpals—the 2nd, 3rd, and 4th. The 1st, 3rd, and 5th metacarpals articulate with one carpal each, the 4th with two, and the 2nd with three. Further, the apposed surfaces of the bases of the 2nd, 3rd, 4th, and 5th metacarpals articulate with each other and, therefore, carry articular facets. The base of the 3rd metacarpal has a styloid process on its radial side posteriorly to which nothing is attached; the base of the 5th metacarpal has a tubercle on its medial side for the insertion of the Extensor Carpi Ulnaris.

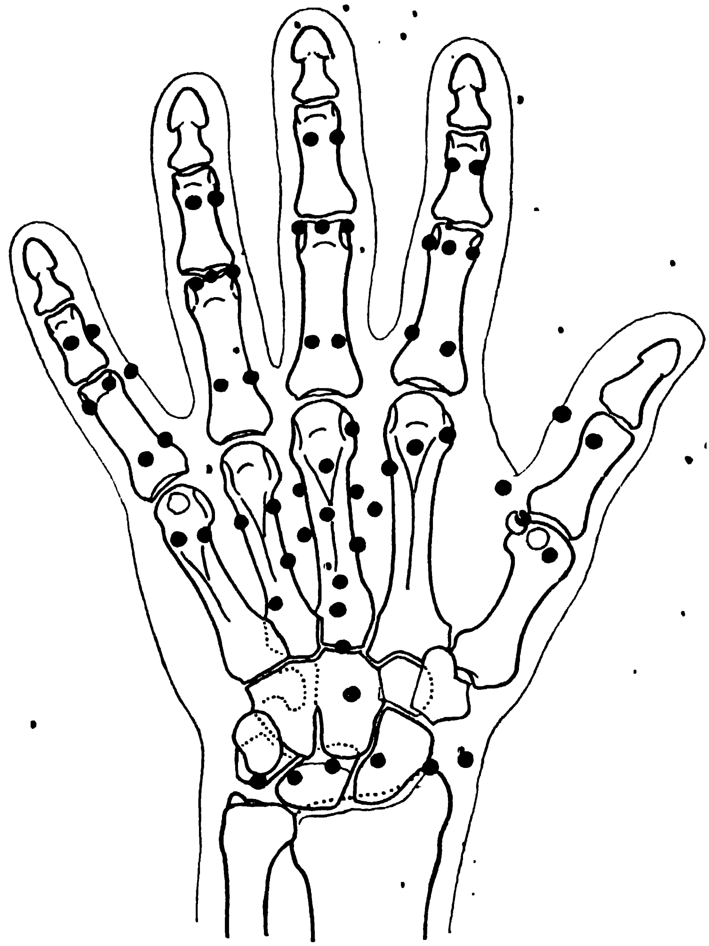


FIG. 123. Tracing of X-ray of hand in which shot was placed on the skin creases to show their relations to the joints (see fig. 115).

THE BODIES OF THE METACARPAL BONES OF THE FOUR FINGERS are triangular on cross-section (*fig. 124*). Each has a rounded, anterior border which separates an antero-lateral from an antero-medial surface. As the antero-lateral and antero-medial surfaces approach the base of the bone they wind dorsally. In con-

sequence of this encroachment, the dorsal surface is rendered triangular and its apex tapers proximally into a line. Its surface is flat. The 3rd anterior border is monopolized by the Adductor Pollicis Transversus; the 2nd, 4th, and 5th by the three Palmar Interossei (*fig. 154*). The opposed antero-medial and antero-lateral surfaces of the five bodies give origin to the two heads of the four Dorsal Interossei. The unopposed surfaces (i.e., lateral of metacarpal I and medial of metacarpal V) afford insertion to the respective Opponens muscles.

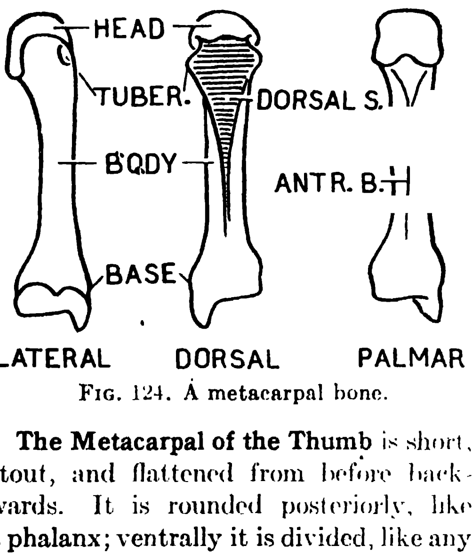


FIG. 124. A metacarpal bone.

The Metacarpal of the Thumb is short, stout, and flattened from before backwards. It is rounded posteriorly, like a phalanx; ventrally it is divided, like any other metacarpal, into antero-lateral and antero-medial surfaces Of these the antero-lateral, for the fleshy insertion of the Opponens, is greater than the antero-medial, which gives origin to the lateral head of the first Dorsal Interosseous. By this you can tell to which side a first metacarpal belongs (*fig. 125*). The base is saddle-shaped. The head is compressed palmo-dorsally; and, in front, a non-articular notch separates the facets on which the two sesamoid bones play.

The Metacarpo-Phalangeal Joints. Observe on your own hand that your knuckles, i.e., the heads of the metacarpals of the fingers, are uncovered when the fingers are flexed, and that these uncovered heads are spheroidal. The bases of the proximal phalanges fit the metacarpal heads and, therefore, are concave or cup-shaped.

The metacarpo-phalangeal articulations of the four fingers can be flexed and extended; and, when the hand is open, they can also be abducted and adducted; that is to say, they can perform the four component movements of circumduction. They, therefore, are condyloid joints

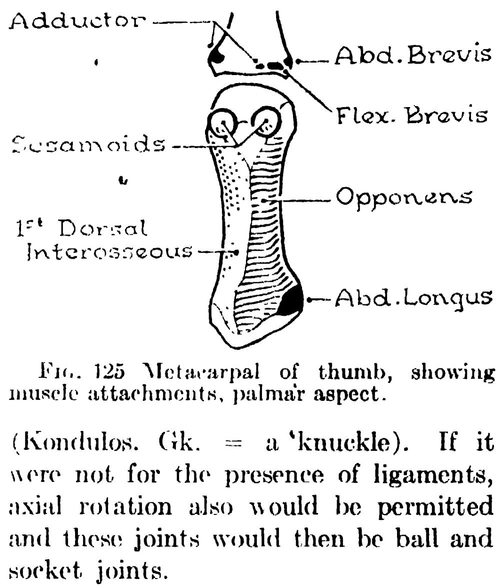


FIG. 125 Metacarpal of thumb, showing muscle attachments, palmar aspect.

(Kondulos. Gk. = a 'knuckle). If it were not for the presence of ligaments, axial rotation also would be permitted and these joints would then be ball and socket joints.

When the joints are flexed, neither abduction nor adduction is possible; and, the reason for this is two-fold: (1) because the heads of the metacarpals, though rounded at their ends, are flattened in front; (2) because the **collateral ligaments,** though slack on extension, are taut on flexion, due to their eccentric attachments to the sides of the heads of the metacarpals. Look, therefore, near the posterior part of the side of the head of a metacarpal for an eccentrically placed *tubercle* and for a *pit*

in front of it to which the collateral ligament is attached (*fig. 126*).

To allow of flexion and extension the anterior and posterior parts of the capsule must necessarily be lax. Posteriorly there are no ligaments to these joints: the extensor (dorsal) expansions of the extensor muscles effectively serve the part. After all, when the hand is closed, it is grasping some object or, if not, the fingers close on the palm; but in neither case is strain put upon the back of the capsule. Anteriorly, the capsule is replaced by a fibro-cartilaginous plate, the **palmar ligament** or **plate** (volar accessory lig.). This plate is firmly united to the front edge of the phalanx, and loosely attached to the metacarpal by areolar tissue. In consequence, if a finger is wrenched off the hand, the plate-like palmar ligament will part from the metacarpal and remain attached to the phalanx. Fibers of the collateral ligaments radiate to the sides of this plate and keep it firmly applied to the front of the head of its metacarpal, visor-fashion.

Why is there a fibro-cartilaginous plate here? In obedience to the law that fibrous tissue, where subjected to friction or pressure, acquires a hyaline matrix, which appears to be protective in function. The plate in question lies between the front of the head of a metacarpal and the flexor tendons; and, though known as the palmar ligament, it is not a bond of union between the two bones that it connects, but is part of the socket of the joint.

The sides of the palmar ligaments of the fingers are united to each other by three ligamentous bands, the **deep transverse ligaments of the palm,** which help to prevent the metacarpals from spreading. They leave the thumb free (*fig. 153.*) In front of the transverse ligaments pass the digital vessels and nerves and the Lumbricales; behind them pass the Interossei. Slips from the four digital bands of the palmar aponeurosis are attached to the transverse ligaments in front; slips from the extensor expansions are attached to them behind.

The Interphalangeal Joints are constructed on the same plan as the metacarpo-phalangeal joints of the fingers. Each possesses collateral ligaments, a palmar fibro-cartilage, and a loose dorsal capsule guarded by an extensor expansion. Their movements, however, are

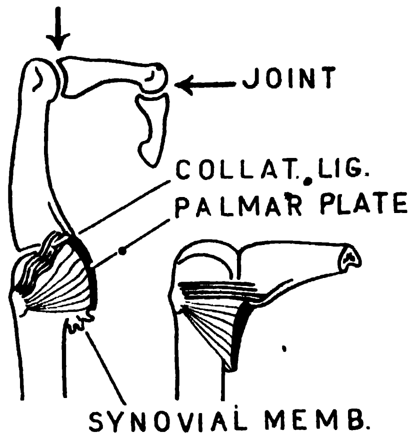


FIG. 126. Metacarpo-phalangeal and interphalangeal joints.

restricted to flexion and extension in consequence of the antero-posterior flattening of the ends of the bones. Patently, they are ginglymus or hinge joints.

The Metacarpo-phalangeal Joint of the Thumb is compressed palmo-dorsally, not unlike an interphalangeal joint; but the head of the metacarpal is rounded and the base of the phalanx is concave. The movements allowed are: flexion and extension, some rocking from side to side, and some rotation.

The Phalanges also are long bones, two for the thumb and three for each of the other digits. They are known as:— the proximal or 1st; the middle or

2nd; and the distal, ungual, terminal, or 3rd (*fig. 127*).

The distal ends of the terminal phalanges are neither weight-bearing nor force-transmitting. In this they resemble the last two ribs, and like them they are tapering. One surface is smooth; the other is rough. The finger nail overlies the smooth surface; the area for the

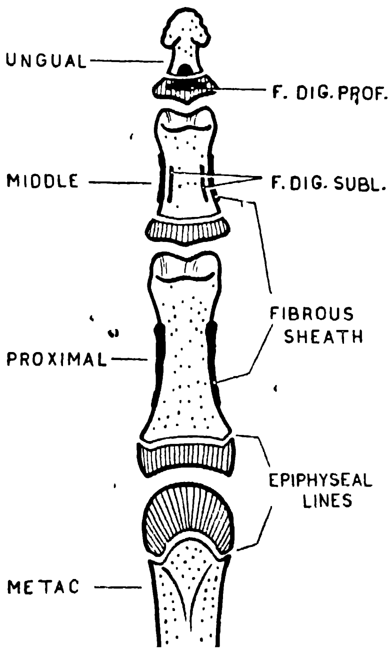


FIG. 127. Phalanges (palmar aspect) showing epiphyseal lines and attachments of fibrous sheath and flexor tendons.

finger-pad is rough owing to the attachment of fibrous bands that bind the skin to it.

The dorsal aspects of the proximal and middle phalanges are smooth, rounded and covered by the extensor expansion. The palmar surfaces take part in the floor of the osseo-fibrous tunnels (*fig. 137*) in which the flexor tendons glide. They are smooth and flat. The borders of the proximal and middle phalanges possess sharp crests for the attachment of the transverse, or rather arched, fibers of the fibrous flexor sheath. Those of the middle phalanx are especially well marked because to them are also attached the slips of insertion of the Fl. Digitorum Sublimis.

When your hand is closed, the heads of the middle and proximal phalanges are uncovered. They have two little condyles, and therein resemble the lower end of the femur. The bases of the terminal and middle phalanges have two little depressions, and resemble the upper end of the tibia. The bases of the proximal phalanges articulate with the rounded knuckles and are concave.

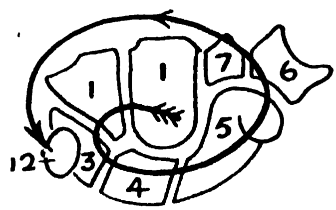


FIG. 128. Spiral sequence of ossification of carpals; ages in years.

Ossification of the Bones of the Hand. The bodies of the metacarpals and phalanges start to ossify during the 3rd foetal month. The carpal bones, unlike the tarsal bones, have not started to ossify at the time of birth, though, in the female, centers may have appeared in the capitate and hamate. The carpals proceed to ossify in orderly spiral sequence, approximately in the following years: capitate and hamate 1st, triquetrum 3rd, lunate 4th, scaphoid 5th, trapezoid and trapezium 6th—and the pisiform 12th (*fig. 128*).

Epiphyses. The long bones have each one epiphysis; in the metacarpals these occur at the heads; in the phalanges at the bases—the metacarpal of the thumb is the exception, for it resembles a phalanx in that its epiphysis is at its base.

The centres of ossification appear in the 2nd–3rd years and fuse in the 17th–19th

year. Epiphyses have been found at both ends of the 1st and 2nd metacarpals (Pryor).

The Palm of the Hand

The upper limb is used as a grasping or prehensile organ. The grasping is done with the hand, the rest of the limb being an adjustable support for the hand. In adaptation, the skin of the grasping or palmar surface of the hand is very thick, and it rests on a protective pliable layer of fat. It is anchored to the underlying tissues by fibrous bands, which prevent it from being drawn off as a loose glove might be. The fibrous bands are most dense at the pads of the fingers where they extent to the bone, along the sides of the fingers, and in front of the palmar aponeurosis. The fat, accordingly, tends to be imprisoned in loculi, as in the breast. So that the grip shall not slip, the skin is corrugated, it is ridged and furrowed, and there is a convenient absence of greasy, sebaceous glands. On the summits of the ridges the mouths of numerous sweat glands open. The disposition of the ridges in arches, loops, and whorls differs in detail from person to person; so does the spacing, the shape, and the size of the mouths of the sweat glands. The impressions left by the ridges and gland mouths are known as *finger prints* (*figs. 129, 130*).

Permanent *skin creases* occur in the hand. On the digits they are transverse; in the palm they have the form of the letter M; the lowest of the three at the wrist is bowed. At the creases there is an absence of fat and the skin is bound to the underlying fibrous tissue. Movements of flexion and of opposition, as you can readily determine, are responsible for the creases. The relation of the creases to the joints is shown in figures 123 and 115. The midpoint of the wrist crease crosses the center of the lunate bone.

The folds of skin, called the *webs of the fingers*, are palmar structures and are not present on the dorsum.

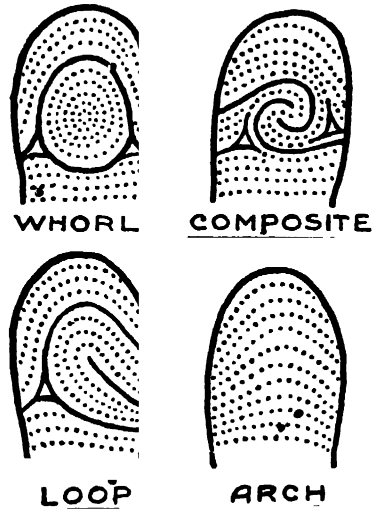


FIG. 129. Types of finger prints. (After Wilder.)

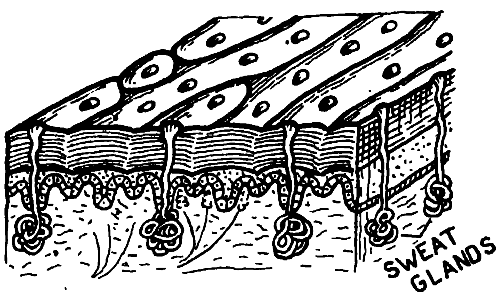


FIG. 130. Friction ridges and orifices of ducts of sweat glands on the fingers. (After Wilder.)

The most projecting digit is the middle finger; next in order come the ring finger, index, little finger, and thumb, so the *digital formula* reads, 3>4>2>5>1 (Wood Jones). This is the primitive arrangement. It is common to apes and man including the N. American Indian. In 19 per cent of white people the index and ring project equally (3>4 = 2>5>1)

and in 33 per cent the index exceeds the ring finger (3>2>4>5>1). Among white females the percentages are higher than among the males (George). A long index is characteristic of white races.

The Movements of the Digits. Note that the thumb is set at right angles to the other digits; that, whereas the nails of the fingers of the open hand face backwards, the nail of the thumb faces laterally; and that, on opening and closing the hand the fingers and thumb move on planes at right angles to each other. These are movements of flexion and extension.

A line drawn through the middle finger is regarded as the *axial line of the hand.* Movement of a finger away from this axial line is called abduction; movement towards it, adduction; and the movements take place at the metacarpophalangeal joints. The thumb also can be abducted and adducted; the movements take place, however, not at its metacarpo-phalangeal joint, but at its carpo-metacarpal joint; the movement forwards (anteriorly) being abduction, and backwards (posteriorly) adduction; that is to say, in the anteroposterior (sagittal) plane you flex and extend your fingers, abduct and adduct your thumb, whereas in the side to side (coronal) plane you abduct and adduct your fingers flex and extend your thumb.

Thus far the thumb appears in nowise superior to a finger. Consider however its carpo-metacarpal articulation where, in addition to the movements of flexion—extension, and abduction—adduction, the further movements of medial and lateral rotation are permitted. It is to these latter movements of rotation that the thumb owes its peculiar value, a value that exalts it above many fingers. The metacarpal of the thumb sits on the trapezium as though astride a saddle, enjoying all the movements of a ball and socket joint. Here, then, we are dealing with a multiaxial joint of the saddle variety (p. 17).

The capsule of the joint is necessarily slack. Now, there are in this loose capsule two ligamentous bands, called the anterior and posterior *oblique carpo-metacarpal ligaments.* These arise from the respective surfaces of the trapezium and converge to be inserted near each other on the ulnar side of the base of the metacarpal. During the act of flexion, the posterior ligament becomes taut and forces the metacarpal into medial rotation; similarly, during the act of extension, the anterior ligament forces the metacarpal into lateral rotation. (Haines.)

The Flexor Retinaculum (TRANSVERSE CARPAL LIGAMENT). The dorsum of your wrist, like the dorsum of your foot, is transversely arched or convex. This arched condition of the wrist or carpus is maintained by a tie-beam, the *flexor retinaculum* (*fig. 131*). The retinaculum forms with the carpal bones an osseofibrous tunnel, the *carpal tunnel.* You can pass a finger through it but not a thumb.

The proximal part of the retinaculum stretches feebly between two rounded prominences, the *tubercle of the scaphoid* and the *pisiform;* the distal part stretches between two crests, the *ridge of the trapezium* and the *hook of the hamate* (*fig. 132*). The crests may be regarded as the ossified ends of the retinaculum. The distal band is always taut; but the proximal band, being attached to the movable pisiform, depends on the Fl. Carpi Ulnaris to steady it. Figure 133 is a true picture of the retinaculum. It depicts the scaphoid as affording the retinaculum but little attachment; the Flexor Carpi Ulnaris as extending its

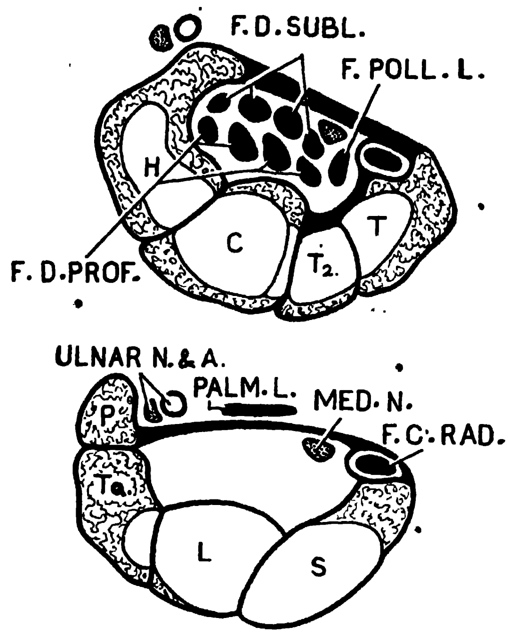


FIG. 131. Proximal and distal rows of carpal bones viewed from above (i.e., distal surfaces of the radio-carpal and mid-carpal joints). The flexor retinaculum and the structures traversing the osseo-fibrous carpal tunnel.

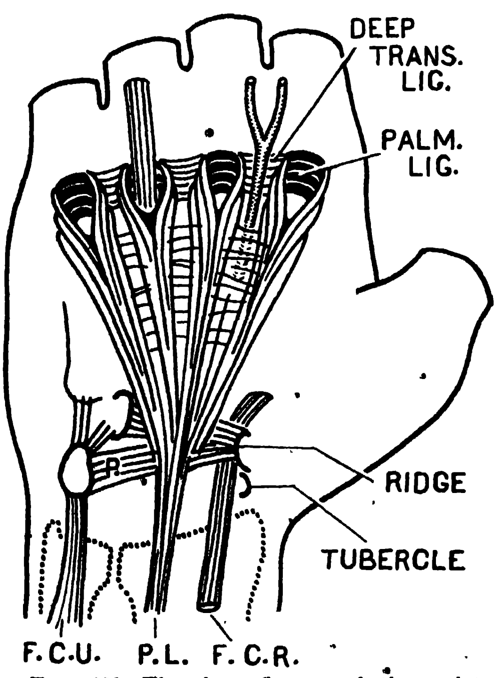


FIG. 132. The three flexors of the wrist: Palmar aponeurosis: Flexor retinaculum.

grasp to the trapezium; the upper border of the retinaculum as blending with the fascia of the forearm; and the lower border is concave owing to the attachments it gives to the short muscles of digits I and V.

By palpating the tendons of your own wrist, you can decide that the Flexor Carpi Ulnaris, as well as the other flexors and extensors of the wrist, is called into play to steady the wrist when the hand grasps an object or makes a fist. Such auxiliary muscular action is known as *synergic action.* The tendon of the Flexor Carpi Ulnaris is relayed beyond the pisiform to the base of metacarpal V and to the hook of the hamate by the *piso-metacarpal* and *piso-hamate ligaments.*

The flexor retinaculum not only acts as (a) a tie beam; but also plays the part of (b) a restraining band that prevents the long flexors of the digits from "bowstringing" when the wrist is flexed; and (c) it affords chief origin to the muscles of the thenar and hypothenar eminences.

The Three Thenar Muscles (MUSCLES OF THE BALL OF THE THUMB) arise together from the flexor retinaculum and its two lateral bony pillars (tubercle of scaphoid and ridge of trapezium). The most superficial of them, the *Abductor Pollicis Brevis,* is inserted into the lateral side of the base of the proximal phalanx of the thumb (*fig. 125*). It is self-evident from its position and attachments that it draws the thumb forwards (i.e., abducts it); and the movement takes place at the saddle-shaped carpo-metacarpal joint.

Reflexion of the Abductor uncovers a fleshy sheet (*fig. 134*) that extends obliquely infero-laterally to be inserted into the whole length of the antero-lateral surface of the metacarpal of the thumb and adjacent part of the base of its proximal phalanx. This sheet re-

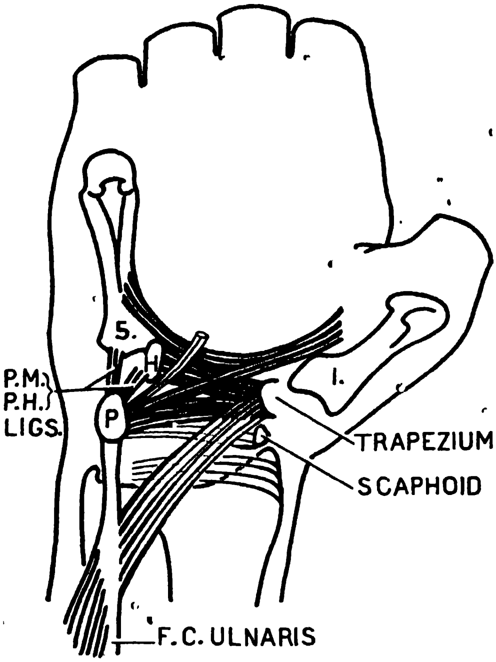


FIG. 133 The flexor retinaculum

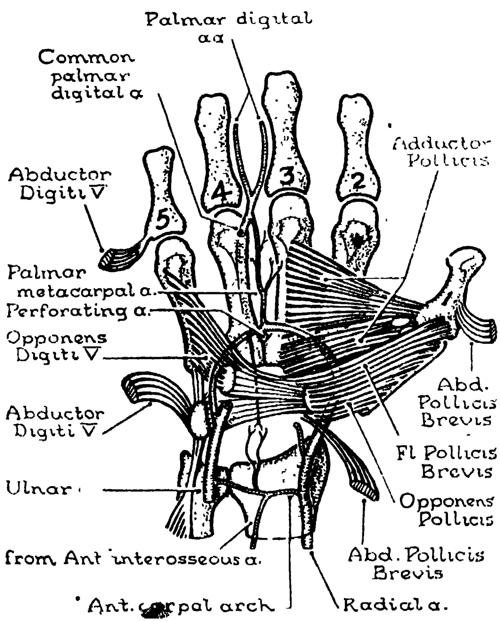


FIG. 134. Short muscles of thumb and fifth digit. Arteries of hand (semischematic).

sembles the Pronator Teres of the radius in direction and in action. On this account it might appropriately be called the "*Pronator Pollicis*". It pronates or medially rotates the thumb at its carpometacarpal joint, and flexes it at its metacarpo-phalangeal joint. The portion inserted into the metacarpal is named the *Opponens Pollicis;'* the portion into the phalanx, the *Flexor Pollicis Brevis* (*fig. 125*). To find the line of cleavage between them, you should expose the metacarpo-phalangeal joint and then, by working proximally, effect a separation of muscle fibers. Because there is little, if any, areolar tissue between the two portions, it is difficult to think that they do other than act and behave as one—opposition is always accompanied usefully by flexion.

The Nerve to the Three Muscles of the Thenar Eminence is easily found. A branch of the median, it takes a recurrent course around the lower border of the retinaculum. It is to be found lying $1\frac{1}{4}''$ vertically below the point where the skin crease, corresponding to the upper border of the retinaculum, crosses the tubercle of the scaphoid (*figs. 135, 145*). A small coin centered on this point will cover the nerve, whose importance is bound up with the importance of the thumb itself. The deep fascia covering the thenar eminence is too thin to afford the nerve much protection, and for practical purposes it is subcutaneous. A cut or a puncture wound of the skin may easily damage the nerve. The superficial palmar branch of the radial artery usually lies along the medial side of the nerve, and, so, serves as a guide to it.

The Three Hypothenar Muscles (MUSCLES OF THE BALL OF THE LITTLE FINGER) are in most respects mirror images of the muscles of the thenar eminence. In

number, in name, in origin, in insertion, and in action the similarity is almost complete. The common origin is from the flexor retinaculum and its two medial pillars—viz., pisiform and hook of hamate.

The Abductor Digiti V springs only from the pisiform, lies along the medial border of the hand, and is inserted into the medial side of the base of the proximal phalanx of the little finger, which it abducts. It acts, note, not on a carpo-metacarpal joint, like the Abductor of the thumb, but on a metacarpo-phalangeal joint. The two deeper muscles, *Opponens Digiti V* and *Flexor Digiti V*, like their namesakes of the thumb, arise from the flexor retinaculum and from a distal carpal bone (the hook of the hamate). Their insertions correspond exactly to those of the thumb. Their fibers run disto-medially.

The Flexor Digiti V appears to be a portion of the Abductor that has spread laterally in front of the Opponens. It is commonly absent.

The little finger cannot be opposed to the other fingers, because the degree of rotation permitted at its carpo-metacarpal joint is trivial. At this joint, however, flexion and extension take place. Verify this by grasping the knuckle of your little finger and moving it forwards and backwards. By the same procedure note that at the 4th carpo-metacarpal joint movements are slight; and at the 3rd and 2nd absent. For the explanation of this, consult the distal surface of the carpus described on page 137.

The Opponens and Flexor Digiti V flex the carpo-metacarpal joint of the little finger and, so, increase the hollow of the palm thereby adapting it for use as a drinking cup or to catching a ball.

These muscles are supplied by the deep branch of the ulnar nerve as it runs between the pisiform and the hook of the hamate.

The Adductor Pollicis. The thumb possesses a fourth short muscle, the *Adductor Pollicis.* It lies in the depths of the palm, arises from the palmar border of the middle metacarpal, from the corresponding carpal bone (the capitate), and from adjacent ligamentous material. It is inserted into both sides of the base of the first phalanx of the thumb (*fig. 134*). The deep palmar arch interrupts its origin, dividing it into a distal *transverse head* and a proximal *oblique head.* Contrary, perhaps, to expectation it is supplied by the ulnar nerve (deep branch). Its lower border is subcutaneous—or more accurately, it is subfascial—and is exposed by removing the skin at the cleft between the pollex and index, that is, at the distal end of the 1st intermetacarpal space. And, after

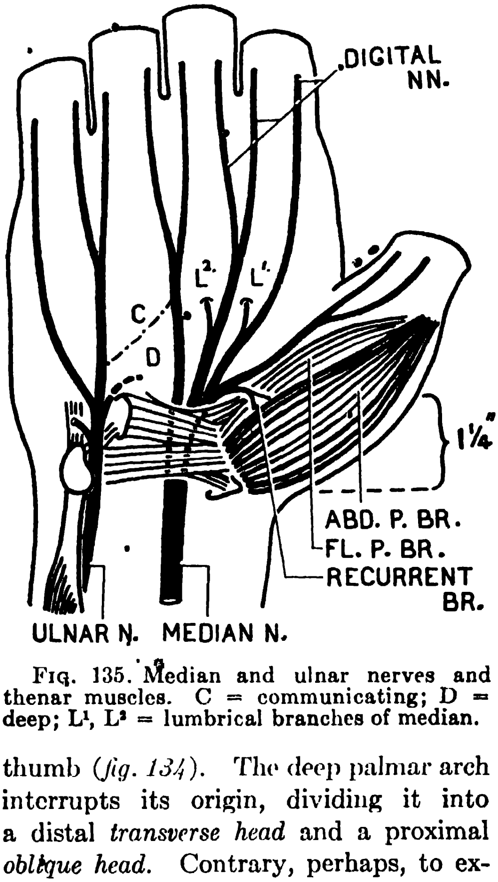


FIG. 135. Median and ulnar nerves and thenar muscles. C = communicating; D = deep; L^1, L^2 = lumbrical branches of median.

removing the deep fascia at the cleft, the space between the Adductor and the 1st Dorsal Interosseous can be opened with the handle of a knife. Obviously the Adductor draws the metacarpal of the thumb across the palm and keeps it applied to the palm.

Opposition is the bringing of the pad of the thumb to the pad of a finger and holding it there, as in pinching, writing, holding a cup by its handle, or fastening a button. Most delicate actions performed by the hand involve opposition. The joint primarily concerned in the movement is the saddle-shaped carpo-metacarpal joint of the thumb.

As regards the thumb, the movements executed are circumduction, rotation, and flexion.

Starting with the three joints of the thumb extended, the complex movement of the opposition is carried out as follows:

Circumduction. The Abductor Pollicis Brevis, acting on the carpo-metacarpal joint, abducts or draws forwards the thumb to the position assumed in readiness to catch a ball. The Opponens and Flexor Brevis continue the circumduction and the Adductor completes it.

Rotation. The Opponens and Flexor Brevis medially rotate (pronate) the thumb. This rotation takes place principally at the metacarpo-phalangeal joint but also at the carpo metacarpal joint, whilst the trapezium moves on the scaphoid and the scaphoid angulates forwards (Bunnell).

Flexion. The short muscles and the Flexor Pollicis Longus are responsible for flexion.

The 3 joints of the opposing finger (or fingers) are flexed by the Profundus, the Sublimis, a Lumbrical, and two Interossei, so that a posture resembling the slightly open claws of a crab is assumed.

The very important Adductor Pollicis closes the "claw-like" thumb firmly against the steadied "claw-like" finger.

Without the Opponens and Flexor Brevis there would be no rotation; without the Adductor the grip would be weak. The median nerve supplies the Opponens and Flexor Brevis; the ulnar nerve supplies the Adductor. Hence, ulnar paralysis results in weak opposition.

The Ulnar Nerve. For reasons given, the ulnar nerve lies medial to its vessels. It enters the hand by passing vertically between the pisiform and the hook of the hamate (*figs. 135, 136*) and therefore in front of the upper part of the flexor retinaculum and the piso-hamate ligament. It is covered first by a slip of fascia, *the volar carpal ligament*, that passes from the tendon of the Flexor Carpi Ulnaris and the pisiform to the retinaculum; and then by the **Palmaris Brevis,** which is a superficial sheet of muscle that passes from the retinaculum to the skin at the ulnar border of the hand. Between pisiform and hamate the nerve divides into a *deep* and a *superficial branch*.

Distribution. The superficial branch supplies cutaneous branches to the medial $1\frac{1}{2}$ fingers and the motor branch to the Palmaris Brevis, and it communicates with the median nerve. Twigs also pass to the joints of the fingers and to the local vessels.

The deep branch supplies the three muscles of the hypothenar eminence, and then curves around the lower edge of the hook of the hamate into the depths of the palm where it supplies all the short muscles of the hand, except the five supplied by the median nerve.

The Median Nerve, after descending through the forearm, crosses the midpoint of the skin crease of the wrist. It there lies medial to the Flexor Carpi Radialis tendon and under shelter of the

Palmaris Longus tendon. It enters the palm through the carpal tunnel. In the tunnel, it adheres to the deep surface of the flexor retinaculum (*fig. 131*). It appears in the palm, covered by the prolongation of the Palmaris Longus called the palmar aponeurosis—so it is fairly superficially placed At once it begins to break up into a "recurrent" and digital branches. These are distributed to 5

1st Lumbrical
2nd Lumbrical } by digital branches

These are shown in figure 135, and the "recurrent" branch is described on page 148

The Digital Branches of the median and ulnar nerves have been identified on the sides of the digital fibrous flexor sheaths (*p. 111*) The digital branches for the

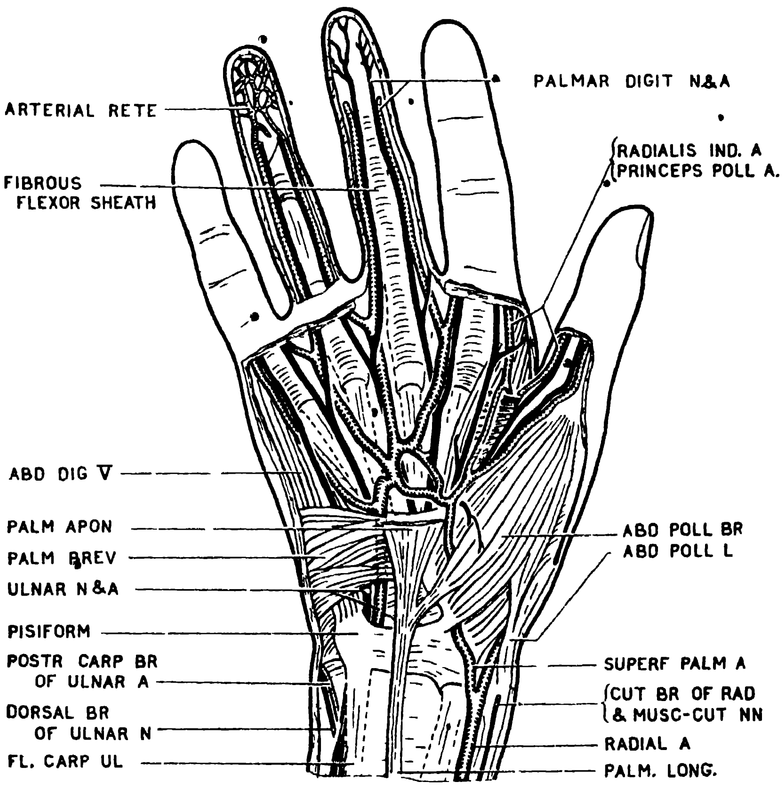


FIG. 136. Superficial dissection of the palm.

muscles and to the lateral 3½ digits, to the joints of these digits and the local vessels.

Motor Branches. The 5 muscles supplied by the median nerve are the 3 thenar muscles and the 2 lateral lumbrical muscles:

Abductor Pollicis Brevis
Opponens Pollicis } by the recurrent branch
Flexor Pollicis Brevis
and

adjacent sides of the four fingers are derived from 3 palmar (or common) digital nerves, which descend to the 3 interdigital clefts and after bifurcating become cutaneous. The palmar digital branches are protected by the tough palmar aponeurosis and are crossed only by the superficial palmar arch. Obviously, the branch to the radial side of the

index and the branch to the ulnar side of the little finger do not bifurcate.

The two digital branches to the thumb descend in the furrow medial to the thenar eminence, where they lie first in front of the synovial sheath of the Flexor Pollicis Longus and thereafter along the sides of its fibrous flexor sheath.

The digital branches of the median and ulnar nerves to the ring finger communicate in the palm, and through this communication the ulnar nerve commonly extends its influence to median nerve territory (*p. 113*).

Palmar Aponeurosis. The Palmaris Longus tendon crosses in front of the flexor retinaculum, gains partial attachment to it, and in the palm divides into four broad, diverging bands of longitudinal fibers that descend to the roots of the 4 fingers, there to be lost in the subcutaneous tissues (*fig. 138*). Dorsal to each band runs a pair of long digital tendons (a Sublimis and a Profundus).

In the distal half of the palm two parallel fibrous septa pass dorsally from each band to be attached to the palmar ligaments and to the sheet of fascia continuous with them that covers the deep muscles of the palm (Interossei and Abd. Pollicis Longus). Ultimately they reach the anterior borders of metacarpals 3, 4, and 5 (*fig. 142*). Thus is the palmar-aponeurosis anchored distally.

The longest and strongest of these anchoring septa lie on each side of the tendons passing to the middle finger. To display them make a longitudinal incision through the band that descends to the middle finger, turn the cut edges aside and with blunt forceps reveal the sharp, curved, proximal margins of the septa. The Palmaris Longus has, then, an antebrachial portion and a palmar portion. The palmar portion is called the *palmar aponeurosis*. It receives an accession of fibers from the retinaculum; so, it is a stronger structure than the antebrachial portion.

The four diverging digital bands are united by transverse fibers. Lying deep to the transverse fibers are the digital vessels and nerves and the Lumbricales.

Structures Crossing the Skin Crease at the Wrist to Enter the Palm. (A) Those crossing superficially have been described. They are:

1. The ulnar nerve and vessels.
2. The Palmaris Longus.
3. The superficial palmar branch of the radial artery (*p. 135*).
4. The palmar cutaneous nerves derived from the ulnar, median, musculocutaneous, and radial nerves (fig. 92).

(B) Those crossing deep, traverse the carpal tunnel. They are:

1. Flexor Pollicis Longus and Flexor Digitorum Profundus, lying side by side.
2. Flexor Digitorum Sublimis: tendons III and IV lie in front of II and V as they enter the tunnel, and lie between them, side by side, as they leave. Tendon V is very slender.
3. The median nerve (and artery when present) clinging to the posterior surface of the retinaculum.
4. Flexor Carpi Radialis, which on its way to its insertion into the base of metacarpal II (*and III*), crosses in front of its elevated pulley, the ***tubercle of the scaphoid***, and then sinks into the vertical groove on the trapezium. It is separated from the foregoing structures by a deep slip of the retinaculum; so, it occupies a private side tunnel.

The foregoing tendons and the median nerve converge from the forearm, traverse the carpal tunnel, and then diverge to the digits. The Flexor Pollicis Longus runs between the three superficial thenar muscles and the Adductor Pollicis.

Fibrous Flexor Sheaths of the Digits. A pair of tendons, *a Sublimis and a Profundus,* descends dorsal to each of the four digital slips of the palmar aponeurosis. In front of the head of a metacarpal bone each pair enters a *fibrous flexor (digital) sheath (fig. 137).* Each sheath extends from the palmar ligament of a metacarpo-phalangeal joint to the insertion of a Profundus tendon into the base of a distal phalanx. Each sheath, therefore, crosses three joints. In front of the joints the sheath must for functional reasons be pliable; here, then, it is thin and its fibers are arranged like the limbs of a St. Andrew's Cross. But in front of the bodies of the proximal and middle phalanges the fibers are transversely curved and are strong, and with the phalanges they form osseo-fibrous digital tunnels which are comparable in structure and function with the osseo-fibrous carpal tunnel.

Insertions of the Digital Flexors. Each Profundus tendon is inserted into the whole breadth of the anterior aspect of the base of a distal phalanx. Each Sublimis tendon splits in front of a proximal phalanx into medial and lateral moities (*fig. 138*). The two central quarters of the split tendon spread apart like the limbs of the letter V and find attachment to the proximal ends of the ridges on the margins of a middle phalanx; the two side quarters twist round the sides of a Profundus tendon, decussate behind it like the letter X, and pass to the distal ends of the ridges on the opposite margins of the phalanx. As a result, the surfaces of the Sublimis tendon are reversed. Each Profundus tendon, therefore, passes through a perforation in a Sublimis tendon; hence, the old terms, Flexor Perforans and Flexor Perforatus.

You would think that a contracting Sublimis would grip the Profundus tendons and arrest them; but it is not so. If you cut across a Profundus tendon and withdraw it from the Sublimis, and then pull on the Sublimis, you will find that the intricate perforation remains so

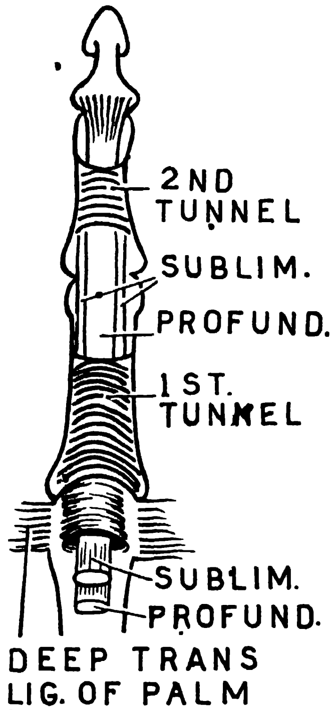


FIG. 137. A fibrous digital flexor sheath showing the two osseo-fibrous tunnels.

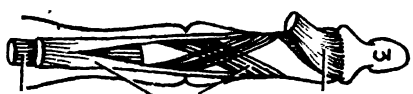


FIG. 138. Mode of insertion of the long digital flexors.

widely open that you can easily thread the Profundus tendon through it again.

The ridges on the margins of the proximal and middle phalanges give attachment to the transverse fibers of the fibrous flexor sheath. Those on the middle phalanx are the better marked because they give attachment to a Sublimis tendon also.

The Lumbricales are four muscles which in shape, size, and color resemble earthworms. They arise in the palm from the Profundus tendons. They lie behind the digital vessels and nerves, and they accompany them in front of the deep transverse ligaments of the palm to the radial side of the fingers, where they join the extensor (dorsal) expansions distal to the attachment of an Interosseous (*figs. 141, 153*). The Lumbricales to the index and middle fingers arise from the radial side only of the corresponding Profundus tendons, and like them they are supplied by the median nerve. The

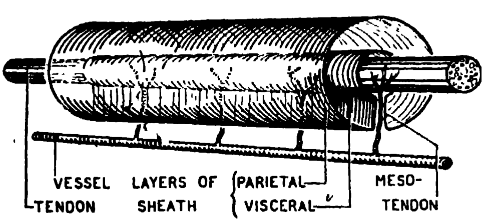


FIG. 139. Diagram of a synovial sheath

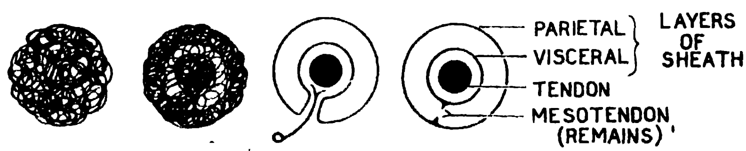


FIG. 140 Stages in the development of tendon, synovial sheath, and mesotendon.

Lumbricales to the ring and little fingers take origin from the ulnar side also of the adjacent tendons and like the corresponding Profundus tendons are supplied by the ulnar nerve.

Note that, by not giving origin to the 2nd Lumbrical, the Profundus tendon to the index enjoys a freedom denied to the other Profundus tendons.

Synovial Sheaths. A synovial or mucous sheath is a lubricating device. It is a bursa that envelopes or ensheaths a tendon; so, it is of tubular form. Indeed, it is a tube within a tube, and the potential cavity between the inner and the outer tube is closed at both ends. You must have noticed that where a muscle plays or rubs against a bone, ligament, or other resistant structure its fleshy fibers are replaced by a fibrous tendon—a tough tissue that requires but little nourishment. It would seem that the vascular, fleshy fibers of a muscle are too highly specialized to withstand pressure. You must also have noticed that between such a tendon and the site of pressure a bursa is invariably interposed to facilitate play and to diminish friction.

It is evident that during flexion of the wrist the long flexor tendons rub on the back of the flexor retinaculum and that during extension of the wrist they rub on the prominent anterior margin of the lower end of the radius and on the carpal bones. Bursae therefore are required both in front of these tendons and behind them. Under circumstances such as this, Nature provides tubular bursae called *synovial sheaths*. They are found only in the hands and feet and around the long tendon of the Biceps Brachii.

Though tendons commonly lie free within their synovial sheaths, it was not ever thus with them, as figures 139 and 140 explain. Every tendon lying within a synovial sheath has, or must at one time have had, a *mesotendon*. A mesotendon is analogous to a mesentery. It is a double layer of synovial membrane that attaches a tendon to the wall of its sheath and conveys vessels to it. It is attached to the side of the tendon least liable to friction. On an average a syno-

vial sheath extends an inch proximal to and an inch distal to the site of friction. But this depends upon the excursion the tendon makes: the greater the excursion, the greater the length of the sheath, and probably the greater the likelihood of the meso-tendon disappearing.

Now, the long flexor tendons (Sublimis, Profundus, and Pollicis) require synovial sheaths first where they pass through the osseo-fibrous carpal tunnel and subsequently where they pass through the osseo-fibrous digital tunnels. They have, therefore, *carpal synovial sheaths* and *digital synovial sheaths.* Of all the digits, the thumb has obviously the freest range of movement, followed in order by digits V, IV, III, and II. This and the shortness of the metacarpals of the thumb and of digit V result in their carpal and digital sheaths coming into contact (*fig. 141*). Those of the thumb probably always unite; those of the little finger fail to unite in about 10 per cent of persons; those of digits II, III, and IV (always) remain discrete. The carpal sheaths of the four Sublimis and four Profundus tendons usually become one, the *Common Flexor Sheath* (Common carpal sheath) with a laterally placed mesotendon. The carpal sheath of the Flexor Pollicis Longus commonly joins the common flexor sheath. In such cases, fluid injected into the digital flexor sheath of the little finger flows into the common flexor sheath, thence to the "carpal" sheath of the Flexor Pollicis Longus, and so to its digital sheath. Equally, an infection starting in the sheath of the little finger may spread by this route to the thumb. The digital sheaths, of course, do not extend distally beyond the insertions of the Flexor Digitorum Profundus and Flexor Pollicis Longus, that is, beyond the epiphyses of the terminal phalanges. A cut, therefore, over the diaphysis of a terminal phalanx will not enter a sheath.

The very end portions of the original mesotendons of the Flexores Sublimis, Profundus, and Pollicis Longus remain as triangular folds, the ***vincula brevia,*** and, several thread-like portions of the mesotendons of the Profundus and Sublimis persist in front of the proximal phalanges

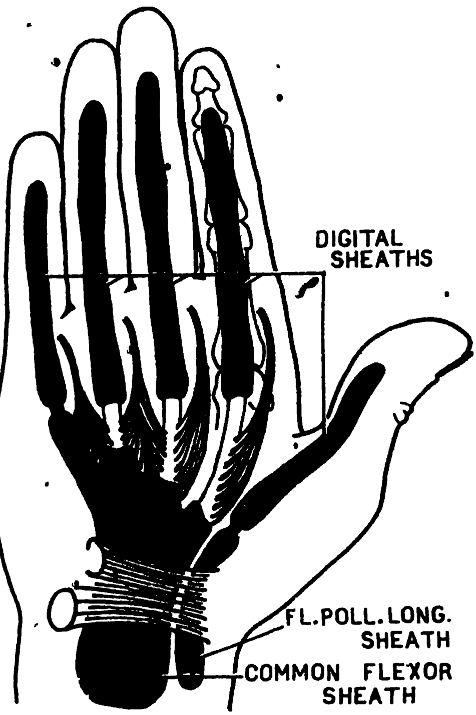


FIG. 141. Synovial sheaths or tubular bursae are required for the long digital flexor tendons at the osseo-fibrous carpal tunnel and at the osseo-fibrous digital tunnels. The Lumbricales are shown.

as ***vincula longa.*** The vincula convey blood vessels to the tendons.

Palmar Spaces (*fig. 142*). There are in the palm four closed fascial spaces. The thenar muscles occupy one, the *thenar space*; the hypothenar muscles occupy another, the *hypothenar space*. Between these two there is a large triangular *central space* that contains the

tendons of the fingers. Its anterior wall is the palmar aponeurosis. Its posterior wall is formed by the three medial metacarpals, the fascia covering the medial Interossei, and the fascia covering the Adductor Pollicis. Its side walls are the backwardly turned edges of the palmar aponeurosis which fuse with the thenar and hypothenar fasciae. The fourth space is placed between the Adductor Pollicis in front and the two lateral intermetacarpal spaces behind.

In the hand, four transversely placed arterial arches unite the ulnar and radial arteries to each other (*fig. 143*). In order of magnitude they are:

(1) The superficial palmar arch, (lying deep to the palmar aponeurosis), and

(2) The deep palmar arch,

(3) The posterior carpal arch,

(4) The anterior carpal arch, (lying on the skeletal plane, i.e., on bone, interosseous membrane, ligament, or the fibrous capsule of a joint).

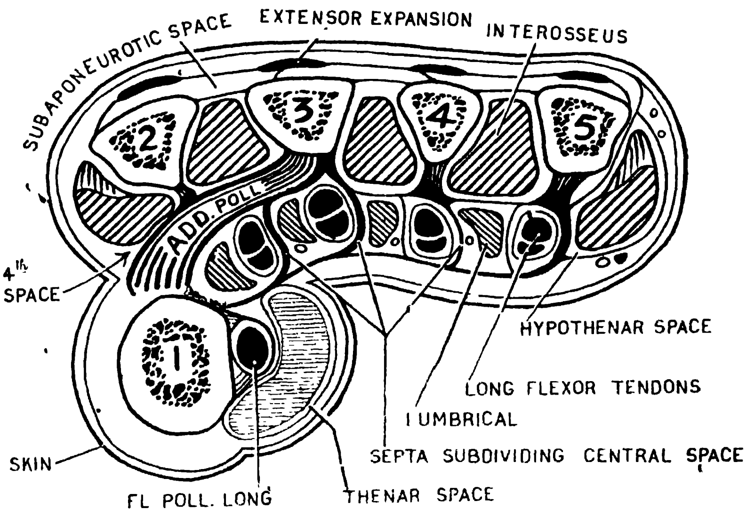


FIG. 142. The palmar spaces in cross-section.

In the distal half of the palm, the central space has 8 subdivisions or tunnels: one being for each of the 4 pairs of long flexor tendons and one for each of the 4 Lumbricals and the companion digital vessels and nerves. The septa separating the tunnels are derived from the palmar aponeurosis. (See page 152.) The tendons of the Lumbricales prolong the spaces downwards on to the dorsum of the digits. It is by this lumbrical route that infection in the central palmar space may spread to the dorsum of the hand.

Arteries. The blood supply to the hand is derived from the ulnar and radial arteries. The supply is good and the anastomoses are excellent.

The Superficial Palmar Arch is the largest, the most distal, and the only superficial arch. It is the continuation of the ulnar artery in the hand. It descends from the lateral side of the pisiform to the level of the web of outstretched thumb and there curves laterally to be completed by one of the following three branches of the radial artery: (a) superficial palmar, (b) digital branch to index or, (c) digital branch to thumb.

The superficial palmar arch lies immediately subjacent to the Palmaris Brevis and the palmar aponeurosis which alone

separate it from the skin. Hence, it is properly called superficial.

As it enters the hand it descends between the pisiform and hamate bones and crosses in turn the upper band of the flexor retinaculum, the pisohamate lig., the Flexor and Opponens Digiti Quinti, the long flexor tendons, the lumbrical muscles, and the digital branches of the median nerve. The deep branch of the ulnar artery arises between the pisiform and hamate bones and accompanies the deep branch of the ulnar nerve.

Laterally, the arch is commonly completed by the superficial palmar branch of the radial artery, which arises as the latter turns into the snuffbox. This branch may be an unimportant thread that ends largely in the thenar muscles or it may be a large vessel whose pulsations can be felt.

Digital Arteries. The superficial palmar arch supplies the medial 3½ digits, leaving the lateral 1½ to the care of the radial artery; it sends one digital branch to the medial side of the little finger and three common digital branches, to the clefts between digits 5 and 4, 4 and 3, and 3 and 2, where they bifurcate into digital branches proper. The (palmar) branches to the lateral 1½ digits arise from the radial artery after it has entered the palm (p. 158).

Note particularly that on the fingers the digital arteries and nerves run side by side in contact not with the phalanges but with the fibrous flexor sheaths (*fig. 144*). It is, therefore, safe to make a longitudinal incision on the side of a digit so long as the knife strikes bone, but an incision made on the side of a fibrous sheath may sever an artery and nerve. The digital nerve lies anterior to its fellow artery.

The Radial Artery, after crossing the Pronator Quadratus, comes into contact with the lower end of the radius. From there until, as the deep palmar arch, it unites with the deep branch of the ulnar artery, it lies in contact with the skeletal plane. Thus, after giving off the *anterior radial carpal* and *superficial palmar arteries*, it turns round the lateral border of the wrist and traverses the anatomical snuff-box to reach the proximal end of the first intermetacarpal space.

It crosses in turn the lateral (radial collateral) ligament of the wrist, the scaphoid and trapezium; and, in turn it is crossed by the three tendons that bound the snuff-box, branches of the radial nerve to the thumb, and the dorsal venous arch.

While in the snuff-box the radial artery gives off the *posterior radial carpal artery*, and sends small branches, *dorsal digital*

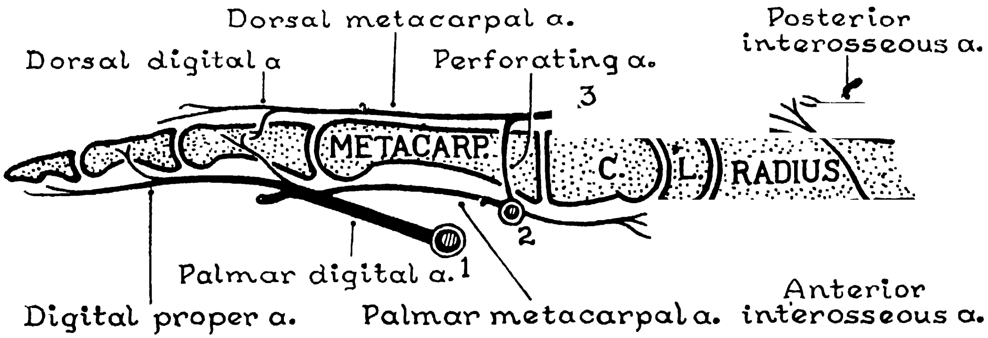


FIG. 143. Scheme of arteries of the hand: The four arches are numbered in order of size—three cling to the skeletal plane.

aa., to the sides of the lateral $1\frac{1}{2}$ digits, passes between the two heads of the First Dorsal Interosseous, and enters the palm to become the *deep palmar arch.*

The Deep Palmar Arch (*fig. 134*) is the radial a. continued into the palm. It is completed medially by the deep branch of the ulnar artery. It crosses the metacarpals just distal to their bases. It interrupts the origin of the Adductor Pollicis, dividing it into a transverse and an oblique head. The deep branch of the ulnar artery, accompanied by the deep branch of the ulnar nerve, becomes deep by curving round the lower border of the hook of the hamate and in so doing it

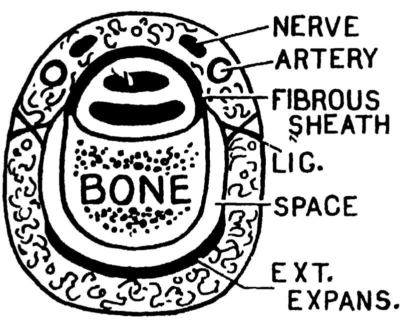


FIG. 144. Section through a proximal phalanx.

interrupts the origin of the Opponens Digiti Quinti.

The deep arch is the great anastomosing artery of the hand (*fig. 134*). Thus, it connects the radial artery laterally, the ulnar artery medially, the anterior carpal arch proximally, the palmar digital arteries distally, and the dorsal metacarpal branches of the dorsal carpal arch posteriorly. In detail, it does so by means of the following branches:

Branches. On entering the palm, the radial artery supplies: (a) *palmar digital branches* to the lateral $1\frac{1}{2}$ digits (viz., princeps pollicis and radialis indicis aa.). These vessels are larger than the dorsal digital branches. They descend between the Adductor Pollicis and the First Dorsal Interosseous, and then follow the sides of the digits in the usual manner. They may complete the superficial palmar arch. Its other branches are: (b) *three palmar metacarpal arteries* which run distally in the three medial intermetacarpal spaces to join the common digital arteries; (c) *three perforating arteries* which pass between the heads of the Dorsal Interossei to join the dorsal metacarpal arteries, (just as the radial artery itself does in the first space); and (d) *several recurrent branches* which run upwards to the anterior carpal arch.

Surface Anatomy. To map the course of the deep palmar arch, feel on the dorsum of your hand for the proximal end of the 1st intermetacarpal space, i.e., where the radial artery enters the palm. Relate this point to the front of the hand, and from it carry a slightly bowed line across the palm to the hook of the hamate.

The Anterior Carpal Arch is formed by the union of the *anterior carpal branch of the ulnar artery* and the *anterior carpal branch of the radial artery.* It lies in front of the lower end of the radius and the proximal row of carpal bones. It anastomoses with (the anterior communicating branch of) the anterior interosseous artery and with recurrent branches of the deep palmar arch to form a rete or network (*fig. 134*).

The Posterior Carpal Arch lies at the back of the wrist between the proximal and distal rows of carpal bones. It is formed by the *posterior carpal branch of the radial artery*, which arises from the radial artery while in the snuff-box, and it is completed medially by a small vessel, the *posterior carpal branch of the ulnar artery*, which has to wind round the medial border of the wrist. The terminal branches of both the anterior and

the posterior interosseous arteries anastomose with it.

Its *branches* are: (a) a branch to the medial side of the little finger, and (b) three dorsal metacarpal arteries. The latter end on the proximal phalanges, and by means of three perforating arteries (in series with the radial artery itself), join the deep palmar arch.

Note again (a) all arteries mentioned in the preceding paragraphs lie on the skeletal plane. (b) The accompanying scheme of the arteries of the hand is self explanatory (*fig. 143*). It will readily be understood that though there are many possible channels at the disposal of the blood stream, they are exploited to different degrees in different persons. (c) The anterior carpal arch is generally very small. (d) When an enlarged median artery is present, it usually either partakes in the superficial palmar arch or, passing directly to the central digits, leaves the medial fingers to the care of the ulnar artery and the lateral ones to the radial artery, in which case there may be no superficial arch. (e) An enlarged perforating artery, associated with either an enlarged palmar or dorsal metacarpal artery, commonly carries the chief volume of blood to a digital artery proper.

CHAPTER 6

THE EXTENSOR REGION OF THE FOREARM AND HAND

(The posterior and lateral aspects of the forearm and the dorsum of the hand)

The muscles covering the lateral surface of the radius, as well as those on the back of the radius and ulna, are supplied

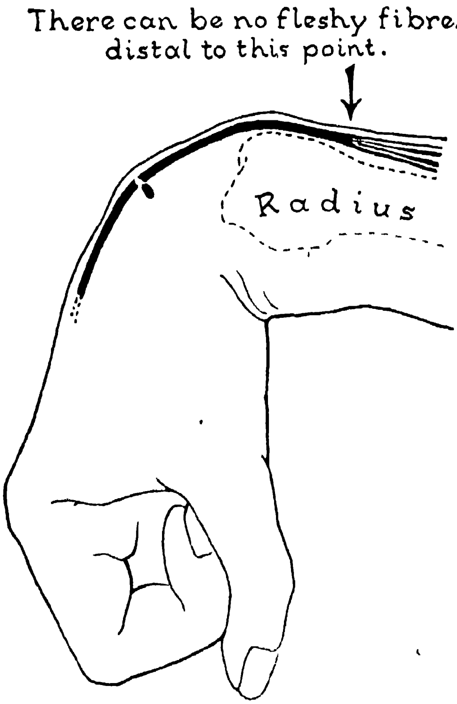


FIG. 145. Fleshy fibers must give place to tendon at the lower end of the radius.

by the posterior cord of the brachial plexus via the radial nerve itself or via its posterior interosseous branch; and, they belong developmentally to the extensor or dorsal surface of the limb (*fig. 110*).

The extensor region of the forearm and hand is sharply marked off from the flexor surface *medially* by the olecranon, the sharp subcutaneous posterior border of the ulna, and the medial border of the hand. *Laterally*, the dividing line is indicated by the radial artery as far as the wrist, and, distal to this, by the lateral border of the hand.

Glance at the dorsum of your hand when it is closed and the wrist flexed, and observe how extensive is the convex bony surface over which the extensor tendons play and press. It extends from the lower ends of the radius and ulna to the finger nails. Therefore, all fleshy fibers necessarily give place to tendon at this level (*fig. 145*), and there are no fleshy fibers distal to it; so, no muscles arise from the dorsum of the hand. Certain muscles are inserted there—but in all instances by long tendons. No tendons are inserted into the dorsum of the carpus. All tendons passing from the forearm to the back of the hand span the carpus and reach the bases of the metacarpals or phalanges. Those passing to the metacarpals are strong and rounded like flexor tendons; they help to steady the wrist. Those passing to the phalanges are weak, flattened aponeuroses resembling thick fascia; little is expected of them. They are not employed against resistance, but are used to open the hand preparatory to grasping an object, and the metacarpals and phalanges are palpable through them.

As there are no fleshy muscle fibers on the dorsum of the hand, but only tendons, there is no occasion for motor nerves, and there are none.

The Subcutaneous and Palpable Parts of the Ulna (*fig. 146*) are: (*a*) the triangular posterior surface of the *olecranon,*

which the subcutaneous olecranon bursa covers. (*b*) The *posterior border* of the ulna; it extends from the apex of the posterior surface of the olecranon to the styloid process. It is sharp in its upper two-thirds because the aponeuroses of the Flexor and Extensor Carpi Ulnaris, which lie one on each side of it, arise from it. (*c*) The *subcutaneous lower third* of the medial surface; it is subcutaneous because neither the Flexor Digitorum Profundus nor the Flexor Carpi Ulnaris is able to utilize it (see p. 132). (*d*) The *head*, and (*e*) the *styloid process*. When you pronate your forearm in order to inspect the back of the hand, the lateral part of the rounded head of the ulna is brought into view. It is, however, covered by the capsule of the inferior radio-ulnar joint. (*f*) The upper, lateral, and medial surfaces of the *olecranon* can be palpated through the muscles attached to them (Triceps, Anconeus, Profundus).

The Subcutaneous and Palpable Parts of the Radius are: (*a*) the disc-like *head*. It lies immediately below the smooth posterior aspect of the lateral epicondyle. When the elbow is extended, the head lies at the bottom of a visible hollow in which its upper margin is easily felt on pressing firmly downwards. When the elbow is flexed and the forearm alternately pronated and supinated, the head can be felt to revolve under the palpating fingers. It is covered by the common tendon of origin of the extensors and the annular ligament of the radius. (*b*) The *lower end of the radius* can be grasped between the fingers and thumb. The rough, crested, anterior margin of the lower articular surface is very prominent. (*c*) And the *dorsal radial tubercle of Lister* projects from the posterior aspect of the wrist, lateral to its midpoint. (*d*) The *styloid process* of the radius lies in the anatomical snuff-box and is half-an-inch below the level of the ulnar styloid process. In order to palpate the tips of these processes, grasp the sides of the wrist between the thumb and index, and press upwards.

The Snuff-Box. When the thumb is fully extended a hollow, called the "*anatomical snuff-box*", can be seen on the dorsum of the wrist, at the root of the

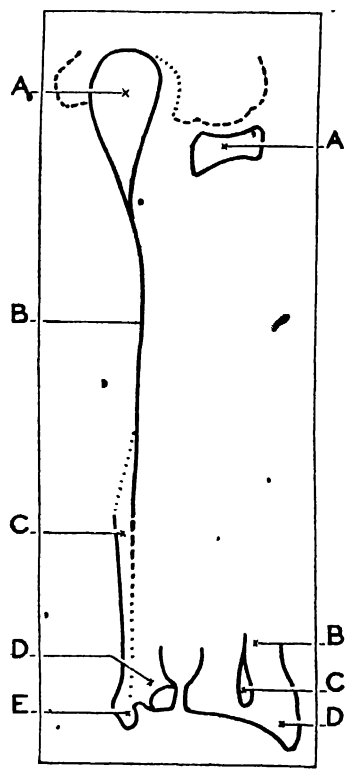


FIG. 146. Palpable parts of ulna and radius, from behind (see text).

thumb. Bounding the snuff-box medially is the tendon of the Extensor Pollicis Longus. Bounding it laterally, and at the same time forming the lateral boundary of the wrist, are the tendons of the Abductor Pollicis Longus and Extensor Pollicis Brevis. These three tendons can be seen in the living subject and should be traced in the dissected limb distally to their insertions. One will be found at-

tached to the base, which is also the epiphysis, of each of the three long bones of the thumb.

Crossing the snuff-box superficially are the beginning of the *cephalic vein* in the dorsal venous arch, and the (*superficial*) *radial nerve*. When these are displaced the *radial artery* can be exposed crossing the snuff-box on the skeletal plane. It descends almost vertically across the lateral ligament and the two marginal bones of the wrist (scaphoid and trapezium) to the upper end of the first intermetacarpal space where, like a perforating artery, it passes between the two heads of the first Dorsal Interosseous to enter the palm.

The Three Tendons of the Thumb should be traced proximally. First, follow the Abductor Pollicis Longus and Extensor Pollicis Brevis to the side of the radial styloid process, and the Extensor Pollicis Longus to the medial side of Lister's dorsal radial tubercle; then, follow them upwards into the lower third of the forearm to the site where they outcrop from the depths (*fig. 117*).

The furrow along which these 3 obliquely running muscles of the thumb emerge is to be opened up as far as the head of the radius. As this involves splitting the intermuscular septum [between the extensors of the radial carpals and the extensors of the digits] the point of a sharp knife must be used. Beyond the head of the radius the incision should be carried upwards along the lateral supracondylar ridge of the humerus as far as the spiral groove. At this level the incision must stop lest the radial nerve be damaged. *This is perhaps the most important single observation for you to make on the back of the forearm*, for the following reasons: The line of the 3 outcropping muscles of the thumb is crossed by no nerve. This makes it the safest and most natural line of approach and entry to the deeper parts of the back of the forearm. Any other extensive intermuscular incision in this region will

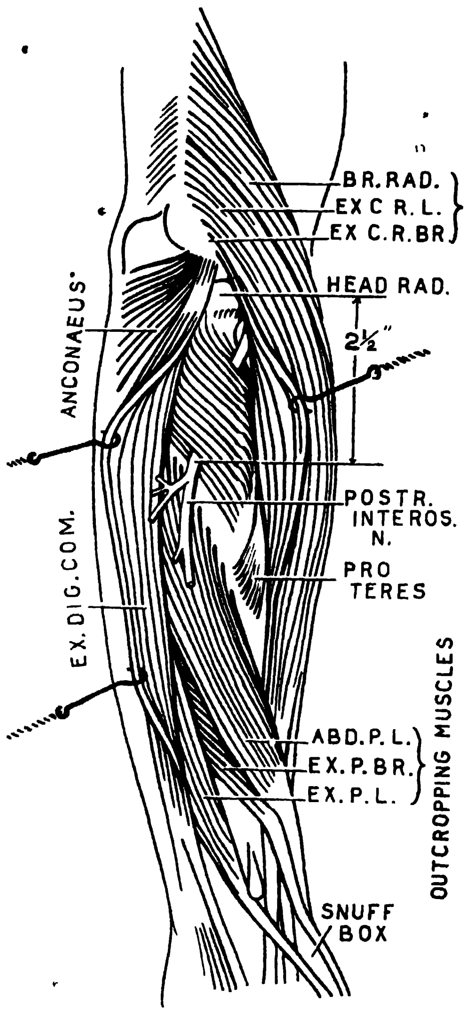


FIG. 117. The furrow of the "three outcropping thumb muscles" opened up—the line of relative safety.

imperil a motor nerve. This is, therefore, *a line of safety* or of relative safety. It divides the superficial muscles at the back of the forearm into a lateral and a posterior group, each with its own nerve supply. On separating the two groups

of muscles, the Supinator, which is one of the deep muscles, is seen wrapped around the upper third of the radius.

The Supinator (*fig. 147*) arises from the lateral ligament of the elbow joint, from the annular ligament, from the triangular hollow (the supinator fossa) below the radial notch of the ulna, and from the ridge behind the hollow. From this origin its fibers, when viewed from behind, are seen to wind in the same direction as the fibers of its antagonist, the Pronator Teres, (i.e., infero-laterally) to be inserted into the body of the radius between the anterior and posterior oblique lines.

The Posterior Interosseous Nerve. (DEEP RADIAL NERVE) is one of the two terminal branches of the radial nerve, the other branch being the (superficial) radial nerve. It arises from the radial nerve in front of the capsule of the elbow joint and under cover of the Brachio-radialis. The (superficial) radial nerve (p. 135) is cutaneous and articular in its distribution, the posterior interosseous nerve is motor and articular.

The posterior interosseous nerve winds round the radius in the substance of the Supinator, which forms for it a fleshy tunnel. It emerges from the tunnel 2½ inches or less below the head of the radius and finds itself under cover of the medial group of superficial muscles. The fleshy tunnel, therefore, conducts the nerve across the furrow of the 3 outcropping muscles of the thumb. The roof of the tunnel is thin; so, it must be respected.

The radial and posterior interosseous nerves together supply the three muscles of the lateral group (Brachio-radialis, Ex. Carpi Radialis Longus, Ex. Carpi Radialis Brevis) and the Supinator before the latter nerve enters the Supinator. On emerging from the Supinator, it proceeds to supply all the remaining muscles on the back of the forearm, the Anconeus as a rule excepted. Its terminal branches supply the wrist and carpal joints. There are no fleshy muscles on the back of the hand for it to supply.

The Muscles of the Extensor Region of the Forearm are arranged in two layers —a *superficial* and a *deep*. The superficial layer is subdivided into two groups a *lateral* and a *posterior*--by the line of the three out-cropping thumb muscles.

The origin of superficial muscles is from a flattened, *common extensor tendon*, which is attached to the anterior aspect of the lateral epicondyle of the humerus, from the investing deep fascia, and from intermuscular septa. The origin of the lateral group of muscles extends up the lateral supracondylar ridge as far as the spiral groove. The common tendon **crosses behind the humero-radial joint and the annular ligament, and therefore behind the head of the radius which is** palpable through it.

THE LATERAL GROUP OF SUPERFICIAL EXTENSORS are:

(1) *Brachio-radialis.*

(2) *Extensor Carpi Radialis Longus.*

(3) *Extensor Carpi Radialis Brevis.*

They are situated lateral to the line of the 3 outcropping muscles of the thumb.

Collectively these 3 lateral muscles are related to the lateral surface of the radius, being separated from it above by the Supinator, in the middle by the insertion of the Pronator Teres; while below they are in contact with the bone. The two radial extensors of the wrist are crossed by all three outcropping tendons of the thumb.

The Brachio-radialis arises from the upper ⅔ of the lateral supracondylar ridge **and lateral intermuscular septum. It bounds the cubital fossa laterally and shelters the radial nerve. Its tendon is inserted in the base of the styloid process**

of the radius. It is peculiar in having both origin and insertion at the distal ends of bones. Its origin rises much higher on the lateral supracondylar ridge than does the origin of the Pronator Teres on the medial supracondylar ridge; and, therefore, being further than the Pronator Teres from the traverse axis of the elbow joint, it acts as a much more powerful flexor of the elbow (*fig. 183*). Bring your limb into the position in which you would carry it in a sling, i.e., the elbow flexed, forearm midway between pronation and supination, the palm facing the chest. Then flex the elbow against resistance, noting how powerfully the Brachio-radialis stands out. Clearly, it acts as a flexor, though developmentally it belongs to the extensor group of muscles and is supplied by an extensor nerve.

The Extensor Carpi Radialis Longus arises from the lower ⅓ of the epicondylar ridge and lateral intermuscular septum.

The Extensor Carpi Radialis Brevis arises from the common tendon, the lateral ligament of the elbow, and the intermuscular septum between it and the Ex. Digitorum Communis. The tendons of the two radial extensors occupy the broad sulcus on the lower end of the radius lateral to the dorsal radial tubercle (*fig. 193*). They cross the snuff box and pass to the bases of the 2nd and 3rd metacarpals.

There is commonly *a bursa* at each end of the Ex. Carpi Radialis Brevis. The one lies between its tendon of origin and the annular ligament; it is said to be inflamed in "tennis elbow". The other lies between its tendon of insertion and the styloid process of the 3rd metacarpal; it is sometimes distended with fluid.

Surface Anatomy. While viewing your own wrist from the radial side, alternately clench and relax your closed fist, observing that the Ex. Carpi Radiales Longus and Brevis tendons spring backwards as the first goes into dorsiflexion (extension). Now, gently grasping your wrist anteroposteriorly, palpate these two tendons as they spring backwards.

THE POSTERIOR GROUP OF SUPERFICIAL EXTENSORS are:

1. *Extensor Digitorum Communis.*
2. *Extensor Digiti Quinti (V).*
3. *Extensor Carpi Ulnaris.*
4. *Anconeus.*

The Three Extensors arise from the common tendon of origin, the deep fascia covering them, and the septa separating them from each other and from the Ex. Carpi Radialis Brevis.

The Ex. Digitorum Communis runs in the most medial groove on the back of the lower end of the radius; with it is the Ex. Indicis. The Ex. Digiti V runs alone behind the inferior radio-ulnar joint. Insertions (see p. 167). The Ex. Carpi Ulnaris plays in the deep groove between the head and styloid process of the ulna. It is inserted into the tubercle on the medial side of the base of metacarpal V. Just proximal to this, you can palpate its tendon from the medial side -particularly when the open hand is extended and adducted.

The Anconeus arises by tendon from the back of the lateral epicondyle. It is inserted by fleshy fibers into the posterior surface of the ulna above the oblique line and into the lateral surface of the olecranon. Developmentally, it is a downward extension of the Triceps. It is covered with a dense fascial expansion of the Triceps, and is supplied by a branch of the radial nerve that descends in the medial head of the Triceps. It can, therefore, be separated from the Ex. Carpi Ulnaris without damage to a motor nerve.

THE DEEP MUSCLES ON THE BACK OF THE FOREARM are:

1. *Supinator* (considered on p. 163).
2. *Abductor Pollicis Longus.*
3. *Extensor Pollicis Brevis.*
4. *Extensor Pollicis Longus.*

They (2, 3 and 4) outcrop in the furrow between the two groups of superficial muscles. They are inserted into the epiphyses at the bases of the 3 long bones of the thumb. 2 and 3 groove the styloid process. 4 winds round a pulley (dorsal radial tubercle) which holds it away from 2 and 3; hence, the "snuff-box".

5. *Extensor Indicis* joins the extensor expansion to the index.

To appreciate these muscles better some knowledge of the dorsal surfaces of the ulna and radius is required.

The Dorsal Surfaces of the Ulna and Radius (*fig. 148*). The dorsal surface of the ulna is crossed by an *oblique line* that passes from the radial notch to the bend on the sharp posterior border at the junction of the upper $\frac{1}{4}$ and lower $\frac{3}{4}$ of the bone. The area above this line belongs to the Anconeus.

The posterior surface of the radius also is crossed by oblique line, the *posterior oblique line*. The area above this belongs to the Supinator. From the oblique line of the ulna a *vertical line* descends and divides the posterior surface into medial and lateral halves. The medial half leads to the groove between the head and styloid process. The Ex. Carpi Ulnaris overlies the medial half and plays in the groove. The lateral half of the posterior surface of the ulna below the oblique line and the whole width of the posterior surface of the radius below the oblique line are utilized by the origins of 4 deep muscles, 3 being for the thumb, 1 for the index (*fig. 148*). They descend in oblique sequence to their insertions, and their tendons do not cross each other; so, there can be no alternative as to their arrangement.

Arteries. Back of the Forearm. The *Posterior Interosseous Artery* is the smaller of the two terminal branches of the common interosseous artery. It does not enter this region with the nerve of the same name, but by passing over the upper border of the interosseous membrane and between the contiguous border

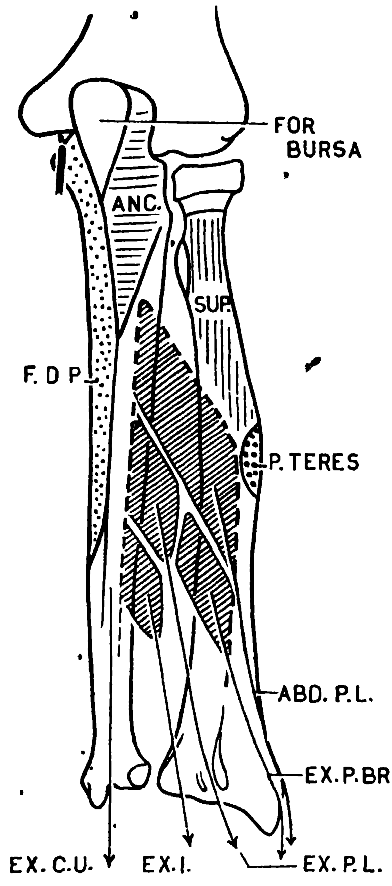


Fig. 148. Posterior aspect of ulna and radius, clothed.

of, the Supinator and the Abductor Pollicis Longus. It descends between the superficial and deep muscles, supplies them, and takes part in the anastomoses at the elbow and wrist.

The branch to the elbow, the *interosseous recurrent artery*, ascends under cover of the Anconeus and anastomoses with

the posterior branch of the profunda brachii artery.

The branch to the wrist joins the *terminal branch of the anterior interosseous artery*, which pierces the interosseous membrane behind the Pronator Quadratus, and descends to anastomose with the dorsal carpal arch (*fig. 143*).

BACK OF THE HAND. While the radial artery is crossing the snuff-box it sends a dorsal carpal branch medially behind the carpal bones. This branch joins the dorsal carpal branch of the ulnar artery to form the *dorsal carpal arch* (*fig. 143*). [The dorsal carpal branch of the ulnar artery reaches the dorsum by crossing the medial lig. of the wrist.] The radial artery itself and the dorsal carpal arch ultimately deliver a small *dorsal digital artery* to each side of the root of each digit, making 10 in all. The radial artery provides the two dorsal digital branches to the thumb and one to the index. The arch sends *3 dorsal metacarpal arteries* distally in the 2nd, 3rd, and 4th intermetacarpal spaces respectively. They bifurcate into small dorsal digital branches for the adjacent sides of the corresponding digits. The arch also provides the branch for the medial side of the little finger. The dorsal metacarpal arteries are joined by *perforating branches* of the deep palmar arch that pass between the heads of the 2nd, 3rd and 4th Dorsal Interossei. The radial artery itself passes between the two heads of the 1st Dorsal Interosseous and is in series with these.

The arteries on the back of the hand lie strictly on the skeletal plane; and any tendons that cross them cross superficially.

Deep Fascia. For a few inches *below the elbow* the deep fascia gives origin to the extensor muscles; so, its fibers are strong and run vertically. Just as the fascia covering the flexor muscles receives an accession of fibers from the Biceps, called the bicipital aponeurosis, so the fascia covering the extensors receives an accession from the Triceps, which may be called the *tricipital aponeurosis*.

At the middle of the forearm the fibers are weaker and less definite in direction, and are attached to the subcutaneous posterior border of the ulna.

At the lower end of the forearm the fibers are required to retain the extensor tendons in place. They might, therefore, be expected to pass transversely between the subcutaneous parts of the

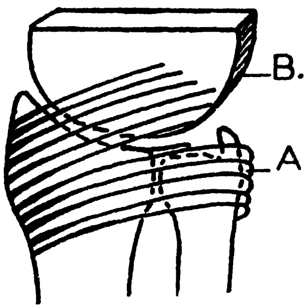


FIG. 149. The extensor retinaculum.

lower end of the radius and ulna. But this could not be, because such a union between the two bones would effectively prevent pronation. This difficulty is overcome, and is overcome to advantage, in the following manner: (a) the more proximal fibers, violating the rule that deep fascia must be attached to all the exposed, subcutaneous, bony points it crosses, turn round the head of the ulna and become continuous with the fascia on the front of the forearm, thereby forming a sort of annular ligament for the head of the ulna (*fig. 149*); (b) and the more distal fibers pass obliquely downwards and medially from the radius to the medial carpal bones (pisiform tri-

quetrum, and hamate) and, because of their direction and attachments, compel the carpal bones, and therefore the hand, to follow the radius during pronation. These strong obliquely set fibers, known as the extensor retinaculum (dorsal carpal lig.) send septa to the radius, thereby forming osseo-fascial tunnels for the tendons. There are 6 of these, each

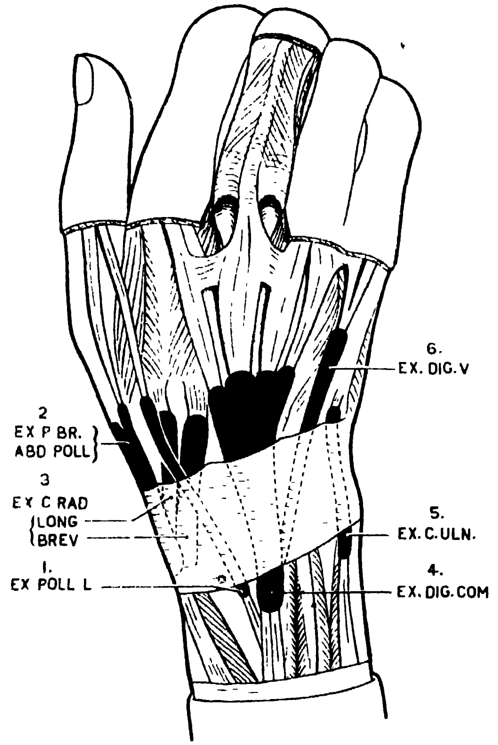


FIG. 150. The 6 synovial sheaths on the dorsum of the hand and a dorsal expansion—see also fig. 151. (Dissection by C. P. Rance and J. W. Rogers.)

lined with a synovial sheath. As at the front of the wrist, so at the back, each sheath extends about an inch proximal to and distal to the extensor retinaculum (*fig. 150*).

Extensor Expansions (DORSAL EXPANSIONS). The four flat tendons of the Ex. Digitorum Communis traverse the most medial tunnel at the back of the lower end of the radius and diverging pass to the four fingers. The common tendons of the index and little fingers are joined on their medial sides near the knuckles by their respective proper tendons; namely, the Ex. Indicis (Proprius) and Ex. Digiti V (Proprius) (*figs. 150, 151*).

The Extensor Indicis tendon enters the hand in the same tunnel as the tendons of the Ex. Digitorum Communis.

The Ex. Digiti V has a tunnel for itself behind the inferior radio-ulnar joint, and it is often the main extensor of digit V, the Communis tendon of digit V being merely an oblique slip.

Three oblique bands unite the four tendons proximal to the knuckles. Hence, the independent action of your

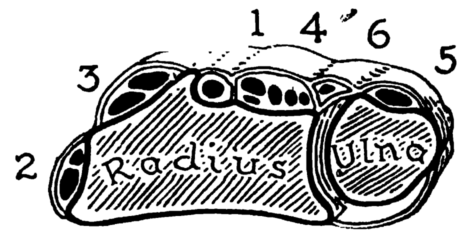


FIG. 151. Figure 150 on cross-section.

fingers is restricted, no one finger being able to remain flexed while the others pass into extension. On flexing each of your fingers in turn, the tendons are seen to move sideways, the direction of the oblique bands is discernible through the skin, and the dorsum of the metacarpal of the index is, on palpation, found not to be covered by an extensor tendon.

STRUCTURE AND ATTACHMENTS (*fig. 152*) on the distal ends of the metacarpals and on the digits the extensor tendons are flattened to the thickness of deep fascia and are called *extensor* or *dorsal expansions*.

Each expansion is wrapped around the dorsum and sides of a metacarpal head and of a proximal phalanx. The *visor-*

like hood, thus thrown over the metacarpal head, is anchored on each side to the palmar lig. or plate and thereby it serves to retain the extensor tendon in the midline of the digit. A broad *fibro-areolar ribbon* passes from the hood to the base of the proximal phalanx.

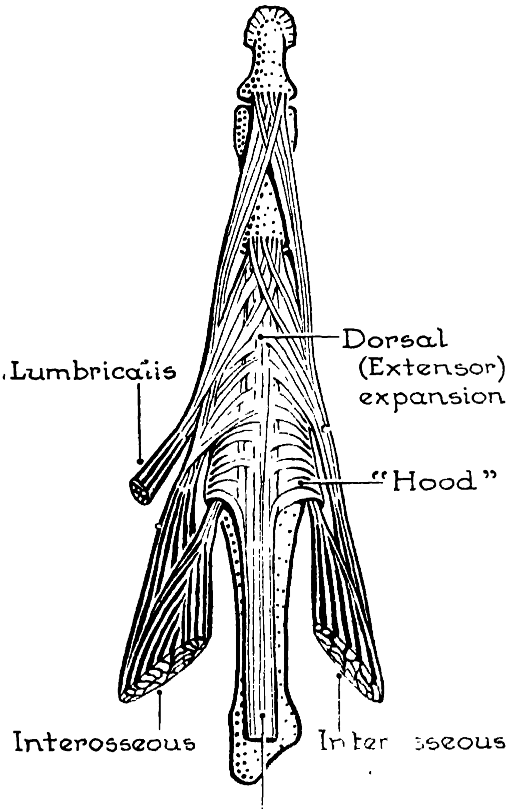


FIG. 152. An extensor expansion.

On the proximal phalanx the expansion divides into a *middle band,* which passes to the base of the middle phalanx, and into *two side bands* which pass to the base of the distal phalanx.

The extensor tendon is inserted mostly via the middle band and only slightly via the side bands.

Each side band is joined by half an Interosseous tendon and more distally, on the radial side, by an entire Lumbrical tendon. These tendons are united across the dorsum of the proximal phalanx by a sling of transverse fibers; and via the side bands they run to the bases of the 2nd and 3rd phalanges.

ACTIONS. The extensor tendons extend the metacarpo-phalangeal joints. The Interossei and Lumbricales extend the interphalangeal joints (*fig. 156*).

Even after an extensor expansion has been cut across, dorsal to a 1st phalanx,

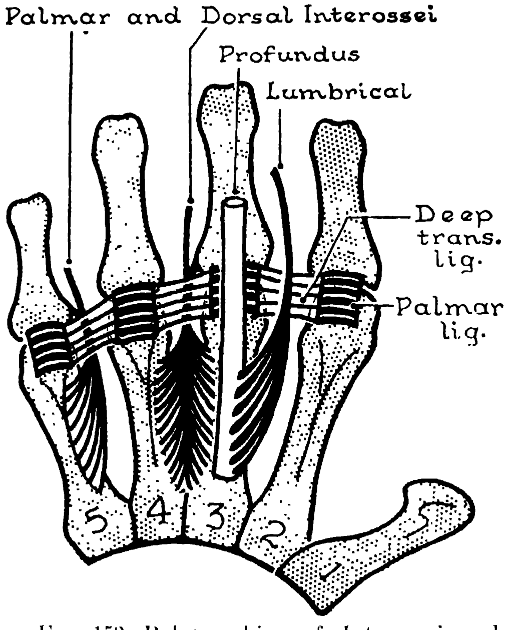


FIG. 153 Relationships of Interossei and Lumbricales to the deep transverse ligaments of the palm, viewed from the palmar aspect.

traction on the corresponding extensor tendon still results in extension of the metacarpo-phalangeal joint due to the pull of the fibro-areolar ribbon attached to the base of the proximal phalanx.

The Interossei and Lumbricales flex the metacarpo-phalangeal joints by means of the slings of transverse fibers that crosses the proximal phalanges. The Interossei have the same functions as the Lumbricales but they are stronger in all movements.

Unless the metacarpo-phalangeal joints are stabilized in extension by the long extensor tendons, the Interossei and Lumbricales are not able to extend the interphalangeal joints nor can they impart side motion (abduction and adduction) to the fingers.

The action of the Lumbricales and Interossei in extending the interphalangeal joints is most powerful when the metacarpo-phalangeal joints are held fully extended, and as these joints are flexing the power diminishes progressively until they are flexed to a right angle, and beyond this point the long extensor assumes full extensor function. (Bunnell.)

The Interossei. **Each of the five digits can be abducted and adducted, that is, moved towards and moved away from a line passing through the middle finger, and called the *axial line of the hand*. For this, 10 muscles are required. The Adductor and Abductores Pollicis attend to the requirements of the thumb, and the Abductor Digiti V abducts the little finger; so, 3 movements are accounted for.**

Interossei account for the remaining 7.

Four Dorsal Interossei (*fig. 155*) are conspicuous from the dorsum of the hand filling the four intermetacarpal spaces and arising by double heads from the adjacent sides of the five metacarpals. By exclusion there are 3 Palmar Interossei.

The 3 Palmar Interossei arise by single heads from the anterior borders of the metacarpals of the fingers with available borders, namely, 2nd, 4th, and 5th (*fig. 154*)—the 3rd anterior border is monopolized by the transverse head of the Adductor Pollicis. Further, each arises from the metacarpal of the digit on which it acts.

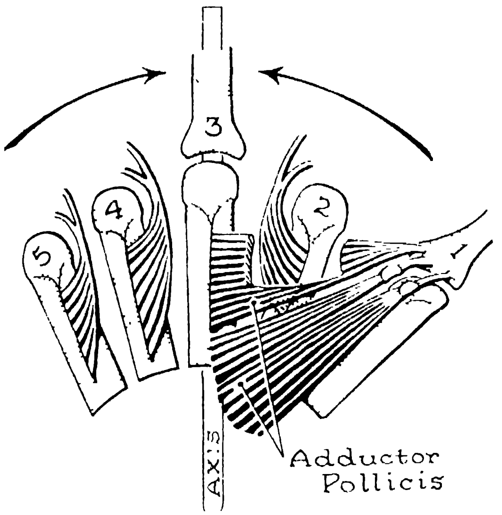


FIG. 154. Three Palmar Interossei.

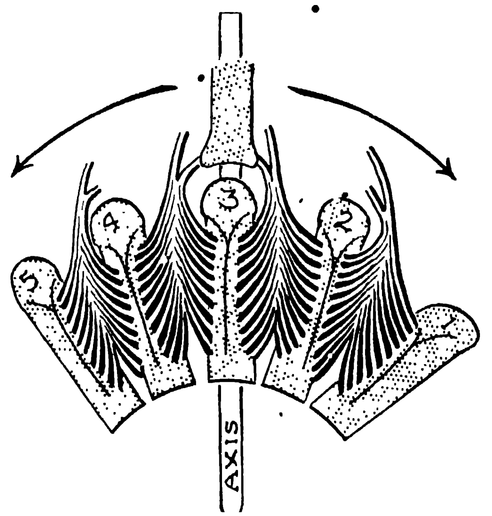


FIG. 155. Four Dorsal Interossei.

Now, the index and ring fingers can be moved away (abducted) from the axial line and the middle finger can be moved to both sides of the line (radial and ulnar abduction)—for these 4 movements the 4 Dorsal Interossei are employed.

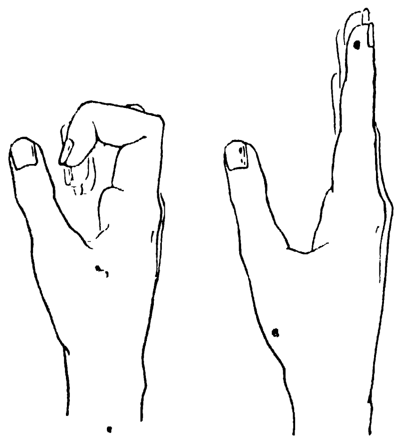
The index, ring, and little fingers require to be moved towards the axial line (adducted)—for these 3 movements the 3 Palmar Interossei are employed.

Course. All 7 Interossei pass behind the deep transverse ligaments of the palm (*fig. 153*); the Lumbricales and the

palmar digital vessels and nerves pass in front.

Insertions. The sides of the fingers to which the Interossei must pass to perform these movements are apparent. Their insertions are partly into the bases of the proximal phalanges and partly into the extensor expansions.

Nerve Supply. All Interossei are supplied by the ulnar nerve. In 3% of 100 limbs, however, the First Dorsal Interosseous was supplied exclusively by the median nerve. The radial nerve may send it fibers, which perhaps are sensory (Sydney Sunderland).



A B

FIG. 156. (A) Long digital extensors. (B) Lumbricales and Interossei.
These extend the metacarpophalangeal and the interphalangeal joints respectively.

Salsbury points out (a) that the Palmar Interossei, except rarely, are inserted wholly into the extensor expansions; (b) that the 1st Dorsal Interosseous is always and only inserted into bone; (c) and that the 2nd, 3rd, and 4th Dorsal Interossei have variable insertions into the expansions and bone, each insertion generally arising from a separate fleshy belly. The 2nd Dorsal Interosseous has a greater bony insertion than the 4th, and the 4th than the 3rd. It is of interest to note that the lateral two Dorsal Interossei are on the same side as Lumbricales and have essentially bony insertions; and that the medial two Dorsal Interossei are on the opposite side to Lumbricales and pass to expansions (chiefly).

When you adduct your thumb (towards the index), the 1st Dorsal Interoseous is seen to bulge; and when you abduct your index against resistance, the 1st Dorsal Interosseous can be felt to become firm, giving the cue that it and the other Dorsal Interossei are abductors.

It is a mistake to commit to memory the attachments and actions of the Interossei when, by such reasoning as is given above, the details can be recalled.

Nerve Supply of the Various Components of the Extensor Expansions.

Radial nerve (Posterior interosseous br.): Extensor Digitorum Communis, Extensor Indicis Proprius, and Extensor Digiti Quinti Proprius.

Ulnar nerve: [Abductor Digiti Quinti], Interossei (all seven), and Lumbricales (digits 4 and 5).

Median nerve: Lumbricales (digits 2 and 3)

Fascial Spaces. If you plunge a needle through one of the flat extensor tendons on the dorsum of the hand and inject a fluid (e.g., plaster of paris, or colored wax), you will reveal a subaponeurotic space (*fig. 142*). It is triangular, the apex being at the wrist, the base at the knuckles. Strong, thin, fibro-areolar membranes connect the expansions to each other and to the sides of metacarpals 2 and 5 which limit the space laterally and medially. The anterior wall is formed by metacarpals 2–5 and the fascia covering the three Interossei between them.

Similar closed spaces exist on the dorsum and sides of each proximal and of each middle phalanx (*fig. 144*).

A LIST OF THE MUSCLES OF THE UPPER LIMB
(This list may be found useful in review work)

Trapezius
Latissimus Dorsi
Levator Scapulae
Rhomboideus Major
Rhomboideus Minor
Pectoralis Major
 clavicular part
 sternocostal part
 abdominal part
Pectoralis Minor
Subclavius
Serratus Anterior
Deltoideus
Supraspinatus
Infraspinatus
Teres Minor
Teres Major
Subscapularis
Biceps Brachii
 long head
 short head
 bicipital aponeurosis
Coraco-brachialis
Brachialis
Triceps
 long head
 lateral head
 medial head
 tricipital aponeurosis
Anconeus
Pronator Teres
Flexor Carpi Radialis
Palmaris Longus
Flexor Carpi Ulnaris
 humeral head
 ulnar head
Flexor Digitorum Sublimis
 humero-ulnar head
 radial head
Flexor Digitorum Profundus
Flexor Pollicis Longus
Pronator Quadratus
Brachio-radialis
Extensor Carpi Radialis Longus
Extensor Carpi Radialis Brevis
Extensor Digitorum Communis
Extensor Digiti Minimi (V)
Extensor Carpi Ulnaris
Supinator
Abductor Pollicis Longus
Extensor Pollicis Brevis
Extensor Pollicis Longus
Extensor Indicis
Palmaris Brevis
Abductor Pollicis Brevis
Flexor Pollicis Brevis
Opponens Pollicis
Adductor Pollicis
Abductor Digiti Minimi (V)
Flexor Digiti Minimi (V)
Opponens Digiti Minimi (V)
Lumbricales
Interossei
 Palmar
 Dorsal

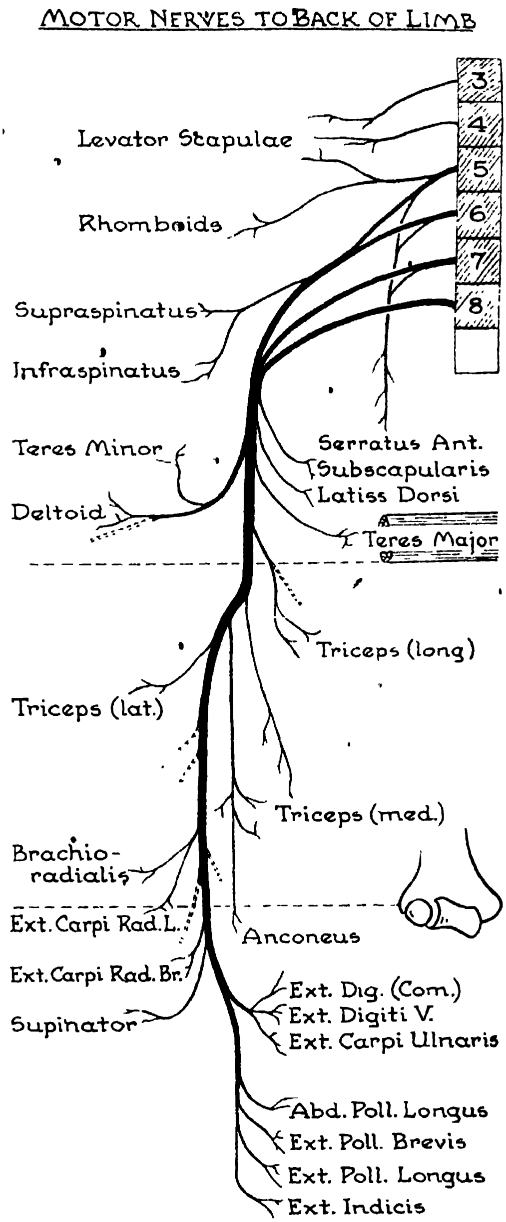


FIG. 157. The motor distribution of the nerves of the back of the limb.

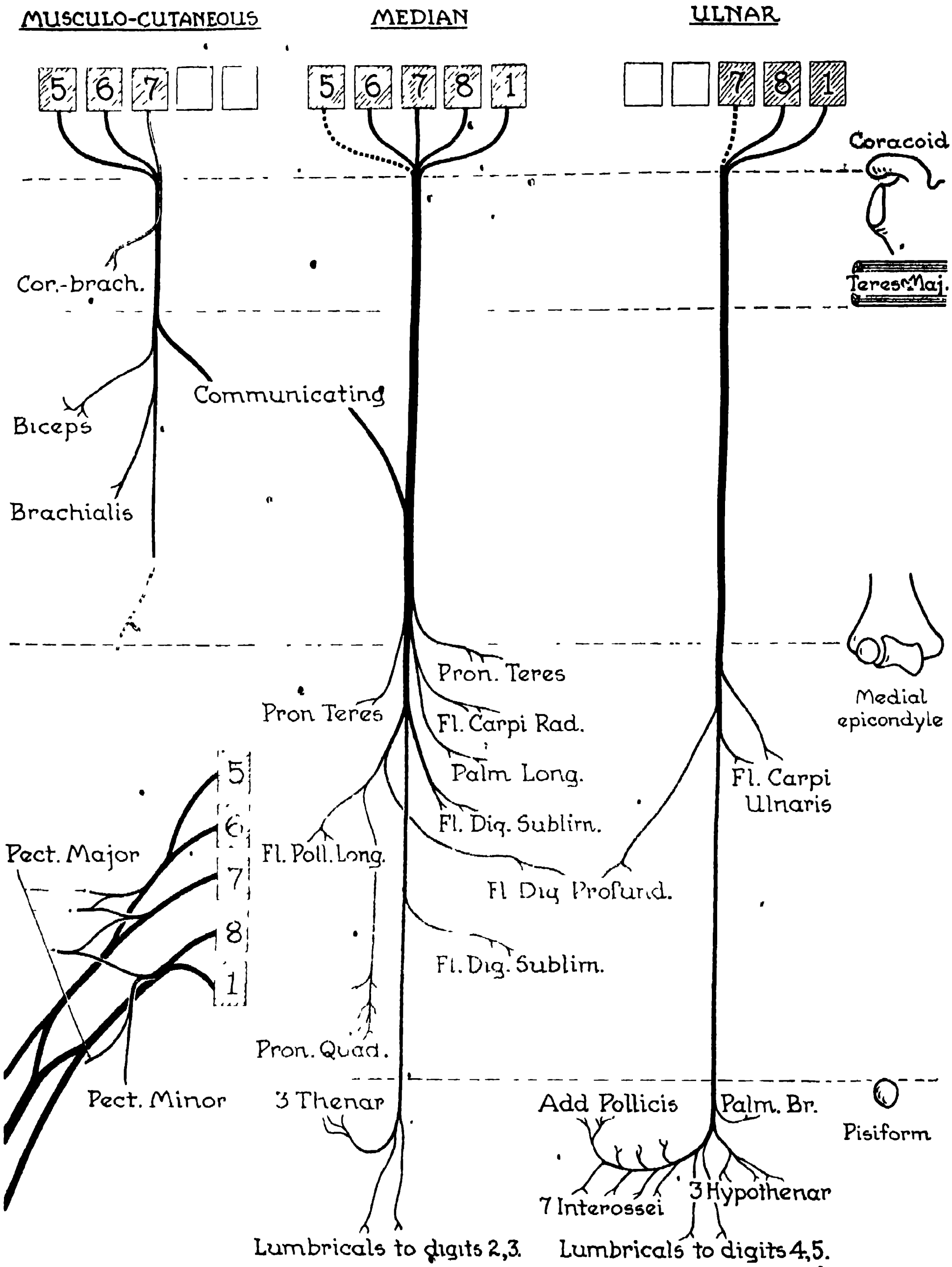


FIG. 158. The motor distribution of the nerves of the front of the limb. (You may find it profitable to compare the levels of origin of the branches in the limb you are dissecting with these average levels.)

CHAPTER 7

JOINTS OF THE UPPER LIMB

Joints in Which the Clavicle Partakes.

1. The Sterno-clavicular joint.
2. The Coraco-clavicular ligament.
3. The Acromio-clavicular joint.

The movements at these three joints augment those of the shoulder joint; and, because the shoulder joint seldom acts independently of them, they should be regarded as auxiliary to it.

When you view in a preparation the various ligaments attached to the clavicle, you are struck by their general *unity of direction*. On consideration, you see that only among certain of them is there *unity of function*.

UNITY OF DIRECTION. The Subclavius—a muscle rudimentary in man—passes from the sternal end of the first rib laterally and upwards to be attached to the under surface of the clavicle between the costo-clavicular ligament medially and the coraco-clavicular ligament laterally (*fig. 159*). Indeed, these two ligaments have been regarded as the degenerated ends of the Subclavius, and all three take a common direction. Incidentally, the ligaments wide of these, namely, the anterior and posterior sterno-clavicular ligaments medially, and the coraco-acromial ligament laterally, share the common direction. Here, then, there is singleness of direction.

UNITY OF FUNCTION. It is practically the sole duty of the clavicle to thrust the scapula, and with it the arm, laterally and backwards and to prevent it from being driven medially and forwards when force is applied to the region of the shoulder. Since muscles can render the clavicle little aid in this, it places its reliance to some extent on the bony contacts it makes at its ends, but mainly on two structures, the *coraco-clavicular ligament* laterally and the *articular disc* medially. From a consideration of the direction of the fibers of the ligament and of the sites of attachment of the disc, you will readily appreciate that between them and the clavicle there is singleness of function; so much so that a fall on the side of the shoulder must put a strain on the coraco-clavicular ligament, on the portion of the clavicle medial to it, and on the articular disc (*fig. 160*).

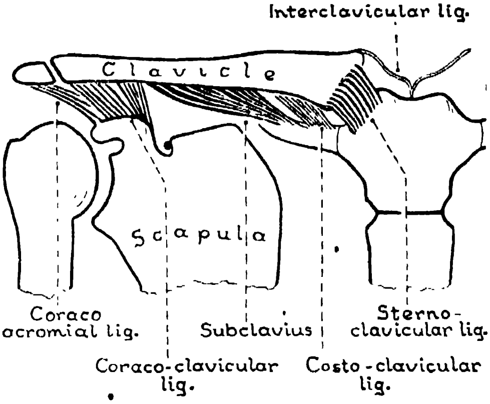


FIG. 159. Structures having unity of direction.

The Sterno-clavicular Joint

Structure. The moderately enlarged sternal end of the clavicle articulates in the socket formed by the saddle-shaped facet at the upper angle of the manubrium and adjacent part of the 1st costal cartilage. The end of the clavicle rises above the manubrium. The two make an ill fit; but a strong, thick, *articular disc* of fibro-cartilage divides the joint cavity into two and overcomes the incongruities of the surfaces. The major use

of the disc—and this is the point—is to prevent medial displacement of the clavicle. This being so, its attachments must be to the clavicle above (actually above and posteriorly) and to the 1st costal cartilage below.

Strong *anterior* and *posterior ligaments*, to which the margins of the disc are attached, strengthen the joint.

A feeble band, the *interclavicular ligament*, perhaps homologous with the wishing bone of the bird, connects the two clavicles across the suprasternal notch.

Movements and Function. As you may discover by palpation, movements at this joint allow the scapula to choose its

FIG. 160. Structures having unity of function.

own position forwards, backwards, upwards or downwards, so long as it keeps its distance from the sterno-clavicular joint. Also, it allows the clavicle to undergo rotation during elevation (pp. 184, 185).

The Costo-clavicular Ligament passes from the 1st costal cartilage to a rough impression below the sternal end of the clavicle. It becomes taut when the arm is protracted and when it is raised above the head. It binds the clavicle to the thorax.

When you stoop to lift a weight, the lateral end of the clavicle sinks and its medial part rests on the 1st costal cartilage, which acting as a fulcrum tends to cause the medial end of the clavicle to be levered out of its socket; but the disc and the anterior and posterior sterno-clavicular ligaments resist.

The disc is not uncommonly found perforated or destroyed (rheumatic arthritis) yet the clavicle remains in its socket. It is held there by other restraining influences: (1) The anterior and posterior thick margins of the disc are not subjected to compression, therefore they are not fibro-cartilaginous but ligamentous. They persist. (2) A strong ligament, hidden by the costo-clavicular ligament, runs medially from the 1st costal cartilage to the lower part of the medial end of the clavicle. (3) To move medially the clavicle must mount the inclined surface of its socket. Doing so renders most surrounding fibers taut.

Relations. Though the joint is palpable and apparently subcutaneous, it is in reality crossed by the flat tendon of the sternal head of the Sterno-cleido-mastoid. Posteriorly, the Sterno-hyoid and Sterno-thyroid form a pad of muscle that separates the great vessels and the vagus nerve from the joint.

Epiphyses. A scale-like epiphysis appears on the medial end of the clavicle about the 18th year and fuses about the 22nd year (*p. 198*).

Nerve Supply. Supraclavicular nerves, and nerve to Subclavius.

The Coraco-clavicular Ligament.

Here there are no articular surfaces—junction is effected by ligaments; so, the joint is a syndesmosis. The coraco-clavicular ligament is in two parts a conoid and a trapezoid. (1) *The Conoid Ligament* is an inverted cone whose apex is attached to a roughness at the medial end of the coracoid process above the suprascapular notch. Its base is attached to the conoid tubercle at the

back of the under surface of the clavicle where the lateral one-third of the bone, which is flattened, joins the medial two-thirds, which is triangular on section. (2) The *Trapezoid Ligament* is placed antero-laterally to the conoid ligament. It is three-quarters of an inch wide and it extends from a rough line on the coracoid behind the occasional site of crossing of the Pectoralis Minor (*fig. 166*) to a rough line on the clavicle.

Function. (A) Owing to their medial (and downward) direction, the conoid and trapezoid ligaments prevent the scapula from being driven medially; in this, only the Serratus Anterior renders them aid.

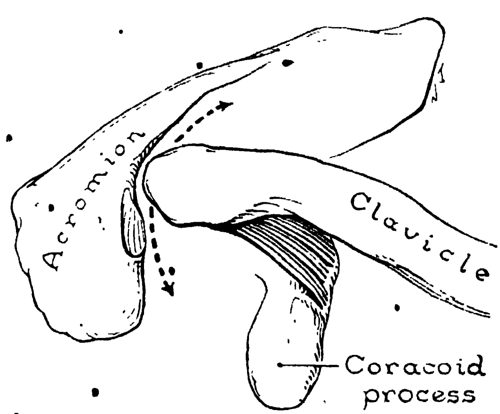


FIG. 161. The acromion may swing forwards or backwards, but, so long as the coraco-clavicular ligament is intact, it cannot be driven under the clavicle.

TABLE 3
Muscles Acting upon the Shoulder Girdle

SIMPLE ELEVATION	SIMPLE DEPRESSION	ELEVATION WITH UPWARD ROTATION OF GLENOID CAVITY	DEPRESSION WITH DOWNWARD ROTATION OF GLENOID CAVITY	PROTRACTION OR FORWARD MOVEMENT	RETRACTION OR BACKWARD MOVEMENT
Trapezius (upper) Lev. Scapulae Serratus Anterior (upper)	Pect. Minor Subclavius and Pect. Major Lat. Dorsi	Trapezius (upper) Trapezius (lower) Serratus Anterior	Rhomboids Pect. Minor Trapezius (mid.) and Pect. Major Lat. Dorsi	Pect. Minor Lev. Scap. Serratus Anterior and Pect. Major	Trapezius (mid.) Rhomboids and Lat. Dorsi

(B) They are the mainstay of the acromio-clavicular joint, and so long as they remain intact, the joint may, indeed, undergo subluxation, but the acromion cannot be driven under the clavicle (*fig. 161*). (C) With the aid of muscles they suspend the scapula.

Relations. The trapezoid band lies almost horizontally above the medial part of the coraco-acromial ligament.

The Acromio-clavicular Joint

The medial border of the acromion has near its tip a small oval facet which articulates with a similar facet on the lateral end of the clavicle. The articular surfaces are so bevelled that an injury, resulting in dislocation, will drive the acromion below the clavicle. Strong parallel fibers form a complete capsule for the joint. A small *articular disc* hangs into the cavity from above.

Function. (1) This joint enables the scapula to move vertically on the chest wall when the pectoral girdle rises (e.g., as when shrugging the shoulders) and falls. Were there no joint here, the inferior angle of the scapula would swing laterally as the clavicle rose. (2) It also enables the scapula, and therefore the glenoid cavity, to rotate forwards and backwards on the clavicle and so to face directions convenient to the head of the humerus (e.g., forwards when striking

a blow)[5]. Also, it is essential to free elevation of the limb (pp. 184, 185).

Epiphyses. The acromial end of the clavicle has as a rule no epiphysis, consequently the sternal end is the more actively growing end, consequently the medullary canal is directed laterally, i.e. away from the more actively growing end. It opens on to the posterior surface of the shaft.

Nerve Supply. Circumflex, suprascapular, and pectoral nerves.

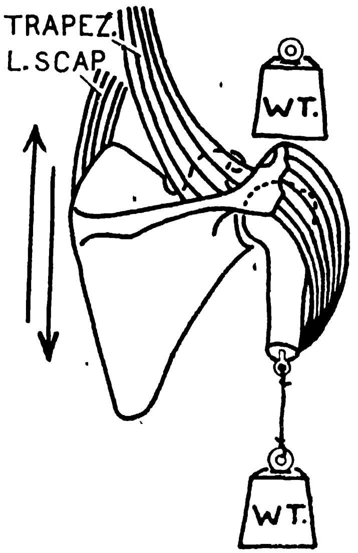


FIG. 162. Simple elevation of the shoulder girdle: The suspensory muscles of the girdle.

Relations. The joint is subcutaneous. The end of the clavicle, being thicker than the acromion, is easily felt on pressing medially with a finger. It marks the site of the joint. Below lie the subacromial bursa and the Supraspinatus.

The student usually fails to appreciate that the apex of the coraco-acromial ligament is attached to the tip of the acromion immediately in front of the joint.

Movements of the Shoulder Girdle.

1. *Simple elevation* of scapula: i.e., the scapula moves vertically upwards. The normal tone of the Trapezius (upper), Levator Scapulae, and Serratus Anterior (upper) is sufficient to suspend the girdle; but when a weight is either supported on the shoulder or carried in the hand, these muscles contract actively (*fig. 162*).

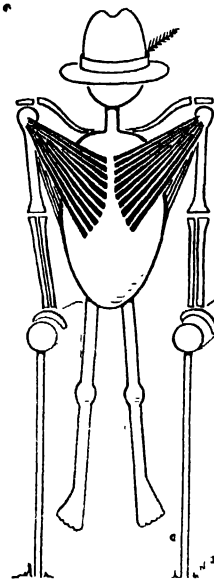


FIG. 163 The timely contraction of the Pectorals and the Latissimus save the clavicle from fracture, when one falls on the outstretched hand.

2. *Simple depression* is brought about by the weight of the limb. But as an active movement, e.g., pressing downwards or resting on parallel bars, it calls into action the Subclavius and Pectoralis Minor, which act on the girdle, and the Pectoralis Major and Latissimus Dorsi, which act on the humerus (*fig. 163*).

3. *Elevation with upward rotation of Glenoid Cavity.* In this movement the acromion rises, the superior angle of the scapula descends, and the inferior angle swings laterally (*fig. 164*). The Trapezius

[5] The conoid lig. checks backward gliding of the acromion at the acromio-clavicular joint and therefore widening of the angle between clavicle and scapula; the trapezoid lig. checks forward gliding.

(upper), Trapezius (lower), and the Serratus Anterior combine in this rotation. With the sinking of the superior angle the Levator Scapulae lengthens; so, it becomes antagonistic to the Trapezius. This movement is almost always part of a larger movement involving either abduction or flexion of the shoulder joint, as when the hand reaches for some object above the head, i.e., the entire limb is elevated—see pages 185 and 186.

4. *Depression with downward rotation*

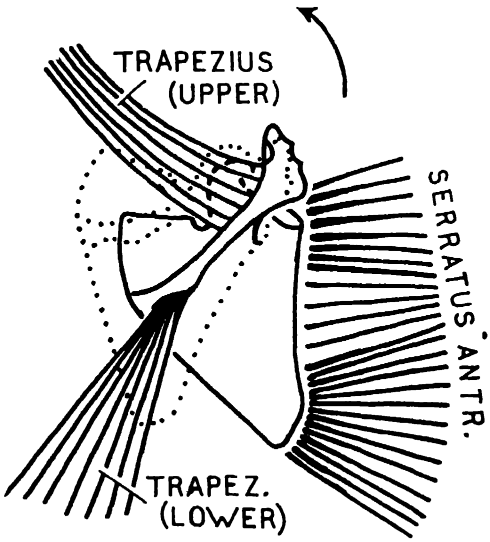


FIG. 164. Elevation with upward rotation of the glenoid cavity.

of Glenoid Cavity, that is, recovering from the last movement or overstepping the recovery, e.g. chopping wood, (*fig. 165*). The Pectoralis Minor, Rhomboids, and Trapezius (especially the middle portion) are called into play; and the Pectoralis Major and Latissimus Dorsi, which act indirectly through the humerus, give them powerful assistance.

5. *Protraction of the scapula* or forward movement, e.g., reaching forwards, pushing, hitting, or carrying the handles of oars forwards in rowing. The Serratus Anterior, Pectoralis Minor, and Levator Scapulae act together with the Pectoralis Major.

6. *Retraction of the scapula* or backward movement, that is recovering from the last movement or overstepping the recovery, e.g., pulling on a rope or bringing the handles of oars backwards in rowing. The Trapezius (middle portion) and the Rhomboids act with the Latissimus Dorsi.

Observe that the Rhomboids and the Serratus, though antagonistic in that they pull the scapula in opposite directions, work together in holding the vertebral

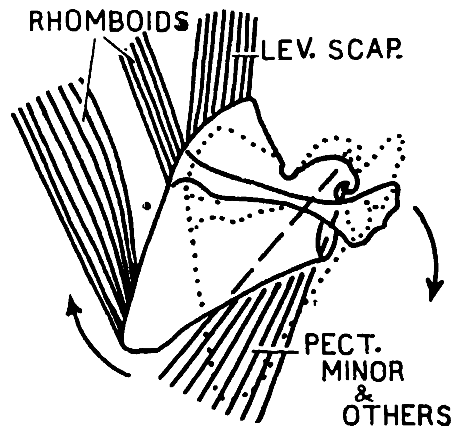


FIG. 165. Depression with downward rotation of the glenoid cavity.

border of the scapula applied to the thoracic wall. Observe also that the Levator Scapulae arises from transverse processes and therefore draws the scapula upwards and forwards; the Rhomboids arise from spinous processes and therefore draw it upwards and backwards.

The Shoulder Joint

The shoulder joint is a ball-and-socket joint, like the hip-joint.

The Ball is the head of the humerus. It forms one-third of a sphere, and faces medially, upwards, and backwards; whereas the head of the femur forms two-

thirds of a sphere, and faces medially, upwards, and forwards.

The *Socket* is the shallow, pear-shaped glenoid cavity of the scapula. At its upper end, that is, at the root of the coracoid process, is the supraglenoid tubercle for the long head of the Biceps. At its lower end, that is, on the axillary border of the bone, is the triangular infraglenoid tubercle for the long head of the Triceps. The playing of the tendon of the Subscapularis across the front of the socket is responsible for the concavity that contributes largely to its pear-shape.

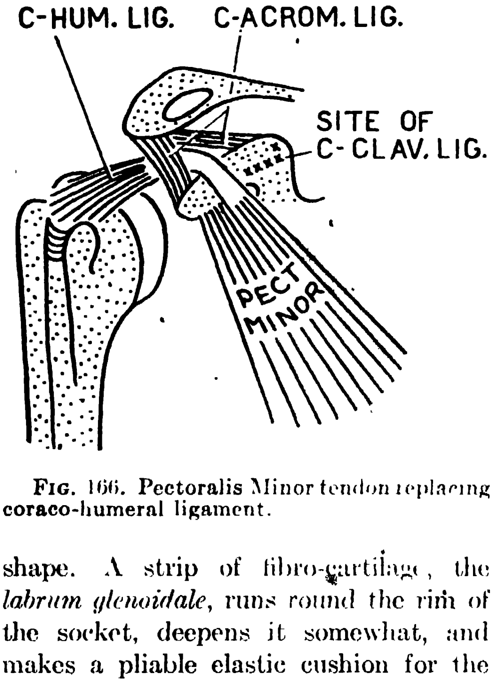


FIG. 166. Pectoralis Minor tendon replacing coraco-humeral ligament.

A strip of fibro-cartilage, the *labrum glenoidale*, runs round the rim of the socket, deepens it somewhat, and makes a pliable elastic cushion for the ball to roll against, (cf. the cushion of a billiard table).

Movements. It is obvious that there is more freedom at the shoulder joint than at any other joint in the body. It is also obvious that the movements permitted are flexion and extension, and abduction and adduction. And, it is not difficult to satisfy oneself that the humerus can rotate medially and laterally on its own long axis. To demonstrate these movements of axial rotation, bend your elbow to a right angle (so that movements of the bones of the forearm shall not confuse), and keep the upper arm close to the side (so that the pectoral girdle shall remain stationary), then swing your hand first medially across your front and then laterally out to the side; and while doing so, palpate the epicondyles of your humerus noting that they rotate with the hand.

Fibrous Capsule and Ligaments. To allow of such free movement, taut ligaments must surely be wanting and the capsule of the joint very loose. Such is the case. In fact, when the shoulder muscles are removed, leaving the humerus attached to the scapula only by the capsule and ligaments, the head of the humerus can be drawn an inch away from its socket.

The *Fibrous Capsule* stretches as a loose tube from just proximal to the margin of the glenoid cavity of the scapula to the anatomical neck of the humerus. Inferiorly, however, it passes well down ($\frac{1}{2}''$) on to the surgical neck. When the arm is adducted, this lower part lies in folds (*fig. 171*).

The Coraco-humeral Ligament has been regarded as the divorced tendon of the Pectoralis Minor; and certainly a portion of the tendon of the Pectoralis Minor may at times be observed passing over the coracoid process and through the coraco-acromial ligament to blend with the coraco-humeral ligament (*fig. 166*). This remark is intended to suggest that the Pectoralis Minor tendon and the coraco-humeral ligament are attached to the coracoid process approximately in line with each other, the tendon being attached to the medial border of the horizontal portion of the coracoid process; the ligament to the lateral

border (*fig. 168*). The distal attachment of the ligament is to the anatomical neck of the humerus beside the lesser and greater tuberosities—which, note, are situated anteriorly and laterally—and its posterior fibers so blend with the capsule that the ligament can only be distinguished from the capsule when viewed supraglenoid tubercle, the *inferior band* contributing fibers to the anterior part of the glenoid labrum en route. The *middle band* may stand out distinctly owing to the fact that the capsular wall has given way both above it and below and so brought the subscapularis bursa into communication with the joint cavity.

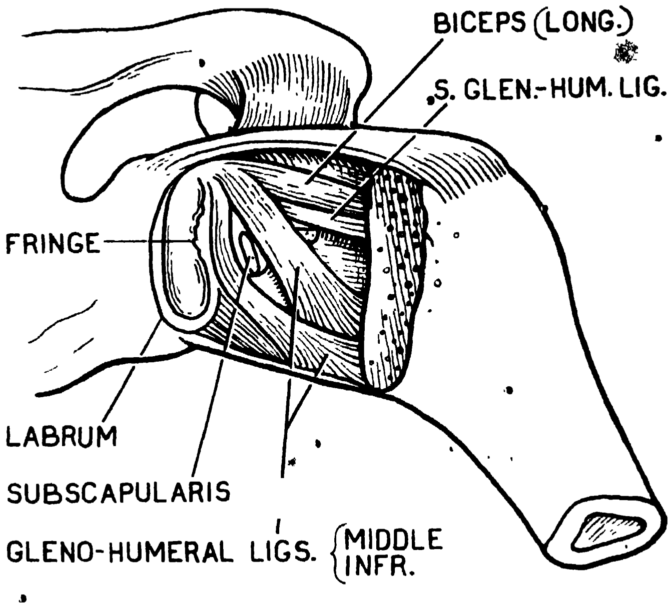


FIG. 167. Interior of shoulder joint (exposed from behind).

from the front. Having these attachments, the ligament must resist lateral rotation and adduction.

If the joint capsule be opened at the back [and, if necessary, the head of the humerus removed], a view will be obtained of the synovial aspect of the anterior part of the capsule (*figs. 167* and *168*). This will be seen to be thickened by three bands, called the superior, middle, and inferior gleno-humeral ligaments, that project into the joint.

The Gleno-humeral Ligaments pass obliquely from the front and lower part of the anatomical neck of the humerus medially and upwards to converge on the In consequence, the *Subscapularis tendon* enters into this picture.

The *superior band* is slender and parallel to the Biceps tendon.

The Long Head of the Biceps may be followed from the bicipital sulcus—which, remember, faces forwards (*fig. 169*)—across the front of the head of the humerus to its origin from the supraglenoid tubercle and posterior lip of the glenoid cavity where it constitutes the glenoid labrum (*fig. 84*). When the humerus is rotated laterally, the Biceps tendon is carried across the summit of the head of the bone. In this position it may play the part of an accessory ligament. The

long head of the Biceps started its development within the capsule, and in early foetal life became free (R. M. Neale). The remains of its original mesotendon is seen as a short synovial fold attaching tendon to capsule near the supraglenoid tubercle. The tendon is retained in the bicipital sulcus by a band, the ***transverse humeral ligament***, that spans the sulcus between the two tuberosities (*fig. 169*).

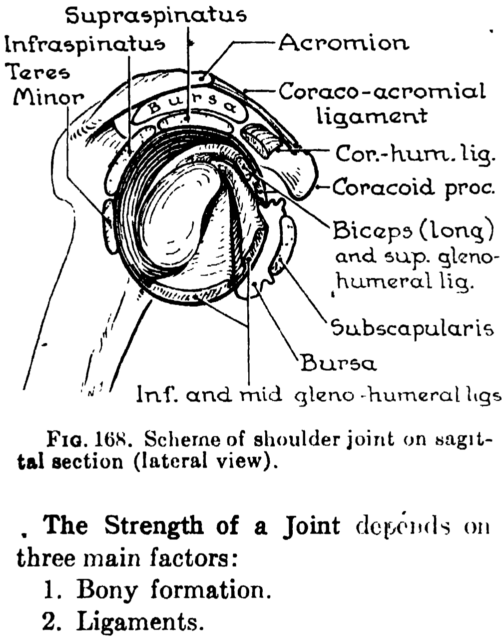


FIG. 168. Scheme of shoulder joint on sagittal section (lateral view).

The Strength of a Joint depends on three main factors:

1. Bony formation.
2. Ligaments.
3. Muscles.

It is evident that for strength the shoulder joint depends neither on its bony socket nor on ligaments, but on muscles. Now, of the muscles around the shoulder joint some are long; others are short. The long muscles perform the movements; the short muscles are disposed closely around the head, and their chief function is to retain it in its socket. In this they have the assistance of the overhanging coraco-acromial arch, which obviously prevents upward displacement of the humerus.

The Four Short Muscles and the Immediate Relations of the Joint. The short muscles round the joint are the Teres Minor and the Infraspinatus behind, the Supraspinatus above, and the Subscapularis in front (*fig. 170*). Their tendons are intimately blended with the capsule. The tendons of these four muscles are in a sense *accessory ligaments*. They are not however passive ligaments, but ligaments active and alert in virtue of the fact that each has muscle fibers attached to its proximal end. They are ligaments under control (*fig. 171*).

Below, there is no supporting short muscle—no alert ligament, but loose unsupported capsule and the quadrangular space. And through this space pass the circumflex nerve, which supplies the Deltoid and Teres Minor, and the posterior humeral circumflex artery.

When the humerus is abducted, the long head of the Triceps and the Teres Major come into contact with the capsule below.

Lying side by side on the insertion of the Subscapularis, and therefore close to the joint, are (1) the neuro-vascular bundle (i.e., the contents of the axillary sheath), (2) the Coraco-brachialis, and (3) the short head of the Biceps which in turn lies side by side with the long head.

Bursae. The tendon of the Subscapularis plays in its groove on the anterior border of the glenoid cavity, where it requires a bursa, the *subscapularis bursa*, to facilitate its play. Here, at the site of friction, bursal wall and joint capsule break down with the result that their cavities come into communication with each other above and below the middle gleno-humeral band. This explains why the Subscapularis tendon can be seen when the joint is opened behind.

The Biceps tendon requires a *tubular bursa* or synovial sheath to lubricate it

where it plays in the upper two inches of the bicipital sulcus (*fig. 172*).

The Subacromial Bursa (*fig. 171*) lies between the acromion and the Supraspinatus tendon, and it extends downwards between the Deltoid and the greater tuberosity. How far downwards? As far as is necessary; that is to say, it covers the part of the greater tuberosity that passes under the acromion during abduction of the humerus.

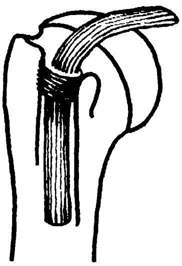


FIG. 169. Upper end of humerus (front view). Long tendon of Biceps and transverse ligament.

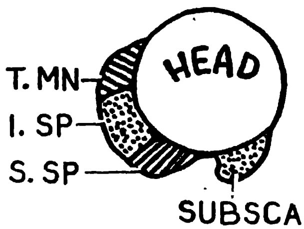


FIG. 170. Insertions of the four short muscles that act as "accessory ligaments" of the shoulder joint viewed from above.

The subacromial bursa is closest to the synovial capsule of the joint at the anterior border of the Supraspinatus.

As the result of wearing away of the Supraspinatus tendon and underlying capsule, it is by no means uncommon for the subacromial bursa to be in wide-open communication with the synovial cavity of the shoulder joint. Fig. 173 represents an advanced stage of this condition. In the initial stages there is a nodular overgrowth of bone in the region of the greater tuberosity and an associated fraying of the capsule. Perforation follows. As the condition advances the soft tissues disappear from under the acromion; it becomes bare. Eburnation of the contact surfaces of humerus and acromion may follow. The intracapsular part of the long tendon of the Biceps becomes frayed—even worn away—leaving it adherent

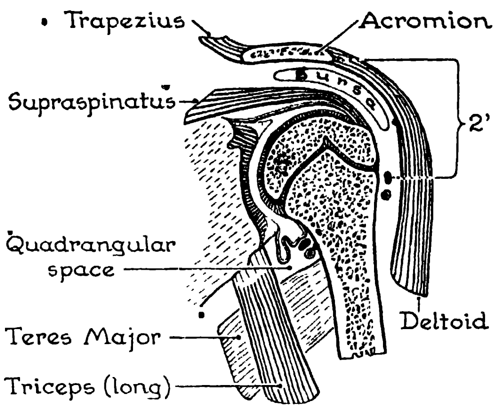


FIG. 171. A young shoulder joint on coronal section. Observe (a) the upper epiphyseal plate; (b) the circumflex (axillary) nerve in the quadrangular space and also 2" below the acromion; (c) the capsule in folds inferiorly during adduction; and (d) the bursa which is both subacromial and subdeltoid.

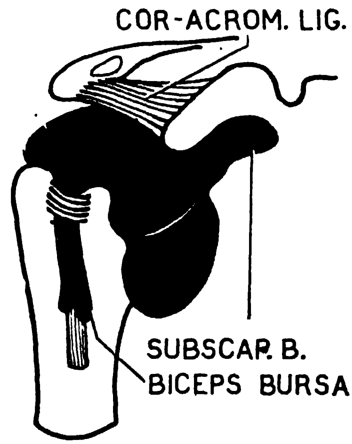


FIG. 172. Synovial capsule of shoulder, distended.

to the bicipital sulcus. Of 79 dissecting room specimens of proved age, none of the 16 under fifty years was perforated; but 3 of the 17 between fifty and sixty years, and 16 of the 46 over sixty were perforated. The condition is usually bilateral.

The Coraco-acromial Arch is formed by the coracoid, the coraco-acromial ligament, and the acromion (*figs. 174, 175*). The ligament is triangular; its apex is attached to the tip of the acromion anterior to the acromio-clavicular joint; its base is attached to the lateral border of the coracoid process.

The Pectoralis Minor may pierce the middle part of the ligament (*fig. 166*)

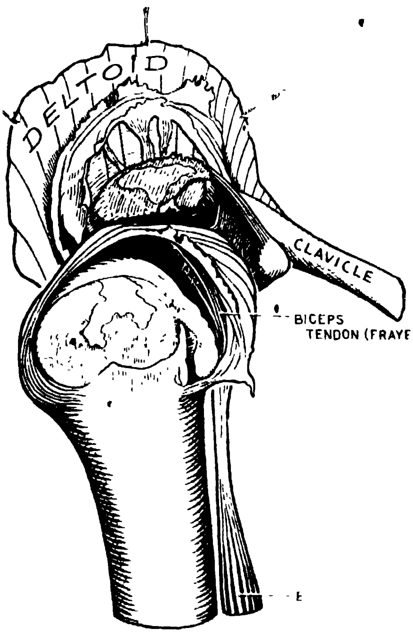


FIG. 173. The supraspinatus tendon and the underlying capsule are commonly worn through (see text).

which is usually weak, in which case the ligament is V-shaped. The arch, with the subjacent subacromial bursa, forms a resilient secondary socket for the head of the humerus, preventing its upward displacement. The coraco-acromial arch does not lie on the arc of a circle centered on the glenoid cavity but is further from it behind than in front (*fig. 174*). Now, when the arm is abducted to a right angle, the greater tuberosity of the humerus impinges on the outer edge of the coraco-acromial arch, and it is easily observed, by following the course of the lateral epicondyle, that on raising the arm still higher above the head, the humerus automatically rotates laterally. Thus is accommodation for the greater tuberosity found under the acromion. It is to allow of this movement that the subacromial bursa is so extensive.

The Epiphyseal Lines are shown in the sketches (*fig. 176*). The epiphyseal line of the *coracoid process* crosses the

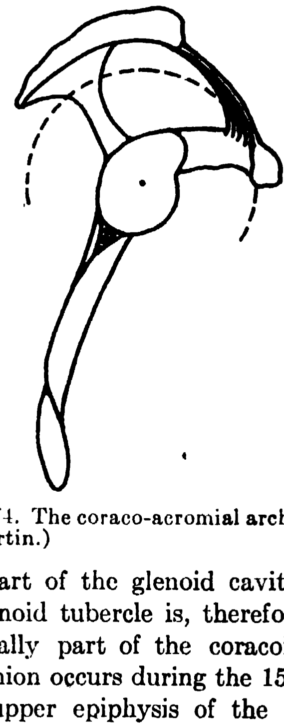


FIG. 174. The coraco-acromial arch. (After C. P. Martin.)

upper part of the glenoid cavity. The supraglenoid tubercle is, therefore, morphologically part of the coracoid process. Union occurs during the 15th year.

The upper epiphysis of the *humerus* rests on the spike-like end of the diaphysis. The epiphyseal line lies at the upper limit of the surgical neck and enters the joint cavity medially. The upper epiphysis of the humerus is an amalgamation of 3 smaller epiphyses: a pressure epiphysis for the head which appears during the 1st year, and 2 traction epiphyses, one for the greater tuberosity (3rd year), the other for the lesser

tuberosity (5th year). All three fuse together before the 7th year, and the resulting single mass fuses with the shaft about the 19th year.

Correct Orientation of Scapula and Humerus. *The Humerus* is to be held vertically, the lesser tuberosity and the bicipital sulcus facing forwards, and the greater tuberosity laterally. Note that the lateral epicondyle and the greater tuberosity face the same direction, and,

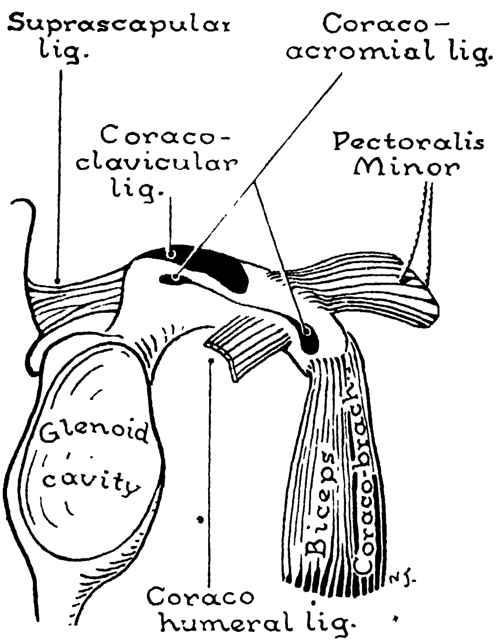


FIG. 175. The structures attached to the finger-shaped coracoid process. (See fig. 58.)

therefore, that in the living subject the one will serve to indicate the position of the other. The backwardly tilted head is somewhat behind the line of the medial epicondyle.

The Scapula, it must be remembered, is applied to the upper part of a barrel-shaped thorax. Hence, its axillary border slopes backwards and is not vertical, as commonly depicted. The tip of the coracoid lies $1\frac{1}{2}''$ supero-medial to the lesser tuberosity of the humerus.

If you cannot orient these bones correctly, you cannot understand: (a) how the Teres Major can act as extensor, (b) why the head of a dislocated humerus almost of necessity passes to the ventral aspect of the scapula, (c) why the coraco-humeral ligament is taut in lateral rotation and in adduction, (d) why the long tendon of the Biceps can abduct only during lateral rotation.

Muscles Acting on the Shoulder Joint. All muscles passing from the clavicle and scapula to the humerus must act upon the shoulder joint; and those passing from the trunk to the humerus must act on the shoulder joint and also on the joints

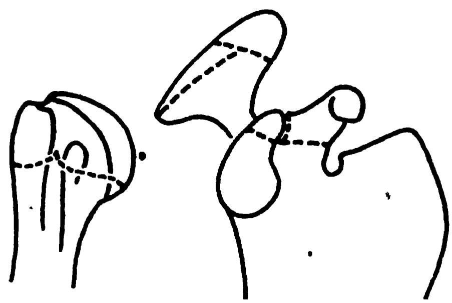


FIG. 176. Epiphyses about the shoulder joint.

of the clavicle (joints of the pectoral girdle). From your knowledge of the bony attachments of these muscles and of the correct orientation of the bones, you will find you are able without much difficulty to apportion to each muscle its proper actions or action and to gauge the relative importance of each. Test your knowledge of the actions of the muscles crossing the joint by entering their names in what you estimate to be the appropriate columns of the blank table; then compare your list with the one appended.

Note that the sternal fibers of the Pectoralis Major bring the humerus from the raised to the dependent position; that the long head of the Biceps

can abduct, if at all, only while the arm is laterally rotated, as only then does its tendon cross the summit of the head of the humerus; that the Teres Major is a powerful muscle—the sectional area of its fleshy belly is almost as large as that of the Biceps; that the long head of the 7th, 8th, and 1st control extension, adduction, and medial rotation. Therefore, if the 5th and 6th segments be paralyzed, the arm will come to occupy the extended, adducted, and medially rotated position—described as the "position of a waiter taking a tip".

TABLE 4

FLEXORS	EXTENSORS	ABDUCTORS	ADDUCTORS	MED. ROTATORS	LAT. ROTATORS

TABLE 5
Muscles Acting on the Shoulder Joint with Their Approximate Spinal Nerve Segments

FLEXION		EXTENSION		ABDUCTION	
Deltoid (clav.)	5, 6	Deltoid (postr.)	5, 6	Deltoid (mid.)	5, 6
Supraspinatus	5, 6	Pect. Major (st.)	7, 8, 1	Supraspinatus	5, 6
Pect. Major (clav.)	5, 6	Teres Major	5, 6		
Biceps	5, 6	Lat. Dorsi	7, 8		
Coraco-brachialis	7	Triceps (long.)	7, 8		
5, 6 (7)		5, 6, 7, 8, 1		5, 6	
ADDUCTION		**MED. ROTATE**		**LAT. ROTATE.**	
Deltoid (postr.)	5, 6	Deltoid (clav.)	5, 6	Deltoid (postr.)	5, 6
Pect. Major (cl.)	5, 6	Pect. Major (cl.)	5, 6	Infraspinatus	5, 6
Pect. Major (st.)	7, 8, 1	Pect. Major (st.)	7, 8, 1	Teres Minor	5, 6
Coraco-brach.	7	Subscapularis	5, 6		
Teres Major	5, 6	Teres Major	5, 6		
Lat. Dorsi	7, 8	Lat. Dorsi	7, 8		
Triceps (long.)	7, 8				
5, 6, 7, 8, 1		5. 6, 7, 8, 1		5, 6	

Triceps can extend the shoulder only when the arm is abducted, for when fully adducted its fibers are too slack; that the Supraspinatus has not the power to raise the arm when the Deltoid is paralyzed.

Reference to the table makes it evident that the 5th and 6th spinal nerve segments control flexion, abduction, and lateral rotation, and that the 5th, 6th,

Nerve Supply: suprascapular (C. 5, 6), circumflex (C. 5, 6), and the nerves to the Subscapularis and the Teres Major (C. 5, 6).

The shoulder joint rarely acts without the assistance of the joints of the pectoral girdle, which may therefore be regarded as auxillary to it.

Elevation of the Upper Limb. The upper limb moves through 180 degrees

when it is raised from the dependent position to a vertical position above the head. This vertical position can be attained either through forward flexion or through abduction. In this movement the sterno-clavicular, acromio-clavicular, and shoulder joints take part simultaneously. Inman, Saunders, and Abbott* have recently shown that during the initial 30 to 60 degrees of elevation, either the scapula remains fixed and the humerus moves or else the scapula moves (it may be laterally or medially) until it finds a position of stability with reference to the humerus. Thereafter the humerus and scapula move in the ratio of 2:1; thus, between 30 and 170 degrees of elevation for every 15 degrees of motion, 10 occur at the shoulder joint and 5 are due to rotation of the scapula. The total range of the shoulder joint movement is 120 degrees and that of the scapula 60 degrees.

The humerus can move through a right angle, if the scapula is held fixed, but its power is diminished by a third. For full elevation of the limb the humerus must undergo lateral rotation, as mentioned already.

The scapula rotates with the permission of the clavicular joints. Thus, the initial movement of the scapula is permitted by the acromio-clavicular joint; then, whilst the humerus is rising, the clavicle rises too, movement taking place (as you can determine by palpation of your own clavicle) at the sterno-clavicular joint until 90 degrees of elevation are reached; and, finally, after 135 degrees the acromio-clavicular joint comes into motion again. The total range of movement of the acromio-clavicular joint is about 20 degrees, and for this the clavicle must be allowed to rotate on its own long axis, otherwise elevation is restricted to 110 degrees. This was determined* by driving a pin into the clavicle of a living subject and manually preventing rotation.

* Observations on the Function of the Shoulder Joint, Journal of Bone and Joint Surgery, Vol. XXVI, January, 1944.

Muscle Force Couples. (*1*) *The Abductors and Flexors of the Humerus.* The Supraspinatus and the Deltoid act together and progressively in elevating the arm. A study of action potential curves (p. 28) shows clearly that the Supraspinatus does not initiate abduction, as is commonly taught, but that both muscles act together throughout the entire range of movement. These elevator muscles, however, are helpless to move the arm away from the side unless the 3 short depressors—Subscapularis, Infraspinatus, and Teres Minor—are in action. These two groups of muscles act as a force couple, the one elevating and the other depressing. Indeed, at 60 degrees of elevation the depressors are actually exerting a greater pull than the elevators, but beyond 90 degrees the force fails rapidly.

The clavicular head of the Pectoralis Major works synchronously with the anterior part of the Deltoid in flexion but, being an adductor, it cannot help in abduction.

The Deltoid exhibits its greatest activity between 90 and 180 degrees.

(*2*) *The Scapular Rotators.* The upper part of the Trapezius, the Levator Scapulae, and the upper part of the Serratus Anterior act as a functional unit. They exhibit an action current potential whilst the limb is at rest because they are passively suspending the limb. They also actively elevate the shoulder region, and they constitute the upper component of the force couple necessary to the rotation of the scapula.

The lower parts of the Trapezius and

Serratus Anterior constitute the lower component of the rotary force couple. The lower part of the Trapezius is more active in abduction; it relaxes somewhat in flexion to allow the Serratus to draw the scapula forwards.

The middle fibres of the Trapezius and the Rhomboids serve to steady the scapula during abduction.

The Elbow Joint

The elbow joint is a hinge or *ginglymus* joint, for it allows only flexion and extension. With it, for reasons that will become apparent, the superior radio-ulnar joint must be considered. There are, in fact, here three joints with one synovial cavity—the humero-ulnar, humero-radial, and superior radio-ulnar joints (*fig. 179*).

The elbow joint being a hinge joint, the following general characters may reasonably be expected:

a. One bony surface will be convex, the other concave.

b. The muscles will be massed in front and behind in order to flex and extend.

c. The capsule will be loose in front and loose behind in order to allow of flexion and extension.

d. Strong collateral ligaments will be required to prevent medial and lateral movements.

e. The medial and lateral bony surfaces will be palpable.

Bones Concerned. THE HUMERO-ULNAR PARTS. *The Lower End of the Humerus* is flattened from before backwards and is set obliquely, being lower medially than laterally. It lies on a plane anterior to the body of the bone and possesses a spool-shaped pulley with sharp edges, the *trochlea*. The trochlea leads in front to a depression, the *coronoid fossa* and behind to a broad triangular hollow, the *olecranon fossa*.

The Upper end of the Ulna presents a triangular bracket, the *coronoid process*, which projects forwards (*fig. 177*). The portion of the ulna continued upwards beyond the level of the coronoid process is cubical, the *olecranon*. If there were no coronoid process, there would be no occasion to refer to the olecranon except as the upper end of the body. Now, the anterior aspect of the olecranon and the superior aspect of the coronoid process articulate with the trochlea of the humerus; hence, they form not a right angled surface but a concavity, the *trochlear* (semilunar) *notch*. This notch is reciprocally saddle-shaped for the trochlea with which it articulates, being, of course, concave from before backwards and convex from side to side. A rounded ridge, which extends from the tip of the ole-

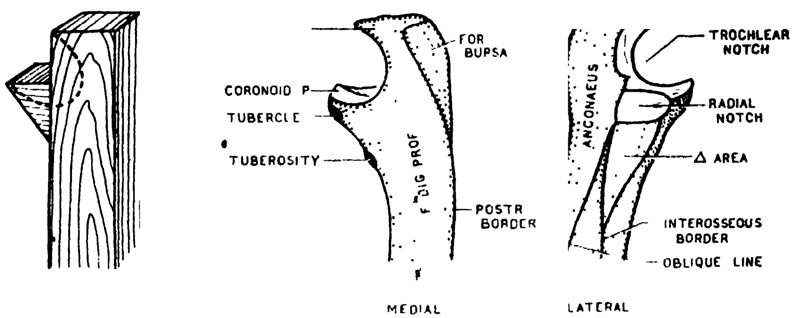


FIG. 177. Upper end of ulna.

cranon to the tip of the coronoid process, divides the notch into right and left portions; and non-articular indentations, indicating where at the time of birth the cartilaginous olecranon united with the body, partly divide the notch into upper and lower portions. Thus, the trochlear notch has four quadrants.

The hinder part of the upper surface of the olecranon is commonly prolonged into a crest by the tendon of the Triceps.

Posteriorly, the olecranon presents a triangular, subcutaneous surface at the apex of which the sharp, posterior border of the body begins. This surface is overlaid by the subcutaneous olecranon bursa.

It is evident that a transverse fracture of the olecranon will bring the joint cavity and the bursal cavity into communication with each other, and that both cavities may be distended with blood poured out from the broken ends of the bone (*fig. 178*).

The medial surfaces of the coronoid process and olecranon merge into the medial surface of the body and like it afford fleshy origin for the Flexor Digitorum Profundus.

The lateral surface of the coronoid process is a concave facet, called the *radial notch* of the ulna, from whose ends two lines descend to meet in the interosseous border of the bone. The triangular depression, enclosed, accommodates the (bicipital) tuberosity of the radius and the Biceps tendon during full pronation of the forearm. The Supinator in part arises from this depression as well as from the line bounding it behind. The Anconeus is inserted into the lateral surface of the olecranon as well as into the posterior surface of the bone as far down as the oblique line.

The Brachialis tendon is inserted into the anterior surface of the coronoid process, where it produces a rough area, the *tuberosity of the ulna.*

THE HUMERO-RADIAL PARTS. The upper concave surface of the *disc-shaped*

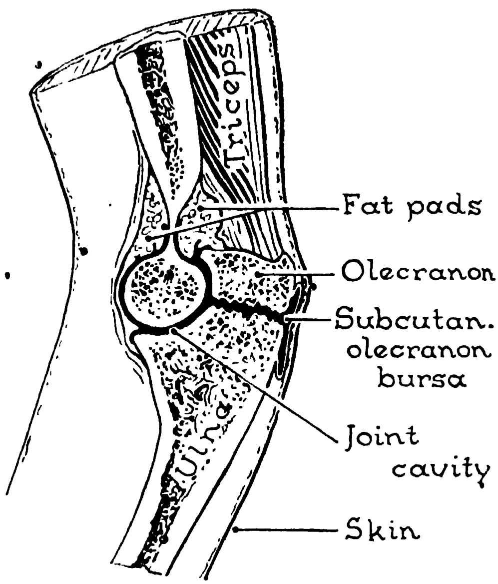


FIG. 178. The joint cavity and the olecranon bursa united by a fracture.

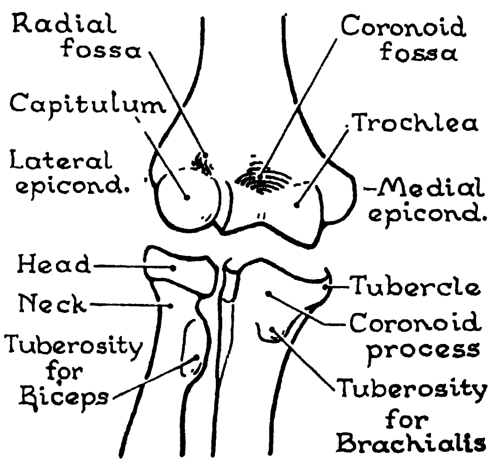


FIG. 179. The bony parts concerned in the elbow joint (front view).

head of the radius rotates on the lower aspect of the distal end of the humerus during extension and on the anterior aspect during flexion. This demands the

presence on the lower and anterior aspects of the distal end of the humerus of a rounded articular *capitulum* or little head. Posteriorly, the capitulum is non-articular. Above and laterally, it merges with the lateral epicondyle. The rim of the upper surface of the disc-like head plays upon the lateral lip of the spool-shaped trochlea which, therefore, helps to prevent medial displacement of the radius (*fig. 179*). During full flexion the rim occupies the radial fossa of the humerus.

The Proximal Radio-ulnar Joint. The head of the radius is held in position by the **annular ligament,** which is attached

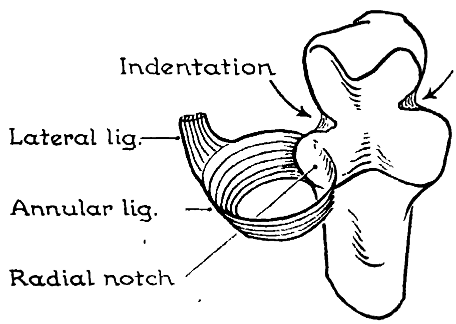


FIG. 180. Socket for head of radius and trochlear notch (from above).

to the ends of the radial notch of the ulna. The notch forms one-fourth of a circle; the ligament three-fourths. The ligament is not strictly speaking annular, but rather it is cup-shaped, being of smaller circumference below than above (*fig. 180*). In consequence, the head of the radius cannot be withdrawn from the cup.

Before the age of seven, the head of the radius is hardly larger than the neck; so, sudden traction on a child's hand or forearm, as when pulling it out of the way of a passing motor car, may result in partial dislocation of the radius downwards.

Ligaments and Capsule. *The Lateral* (*radial collateral*) *Ligament* of the elbow joint is fan-shaped. It extends from lateral epicondyle to the side of the annular ligament; so, indirectly it helps to retain the head of the radius in position. From it the Supinator and the Extensor Carpi Radialis Brevis in part arise. The lateral ligament would, indeed, seem to be the original tendon of origin of the Supinator detached to form a ligament.

The Medial (*ulnar collateral*) *Ligament* of the elbow joint extends in a fan-shaped manner from the lower part of the medial epicondyle to the medial margin of the trochlear notch. The humeral attachment is not quite centrally placed, but is so spread out that the posterior fibers are taut in flexion; the anterior in extension (*fig. 181*). The anterior fibers form a thick cord that is attached to a tubercle on the medial side of the coronoid. From this cord, as well as from the humerus at one end and the coronoid at the other, the Fl. Digitorum Sublimis in part arises. It would, indeed, seem that this cord was Sublimis tendon modified to form a ligament. Some fibers stretch transversely from the medial border of the coronoid to the medial border of the olecranon and serve to deepen the trochlear notch medially.

The Fibrous Capsule occupies the intervals between the medial and lateral ligaments and therefore has an anterior and a posterior portion. It extends to the upper margins of the coronoid and radial fossae in front, but not quite to the top of the olecranon fossa behind. Below, it is attached to the margins of the trochlear notch except laterally where it is attached to the annular ligament.

The Synovial Capsule does not reach so high in the radial, coronoid, and olecranon fossae as the fibrous capsule. The intervals between the two capsules in these regions are filled with fat, fluid at

body temperature, and known as *Haversian glands.* Below, however, the synovial capsule bulges a quarter of an inch below the lower free margin of the annular ligament and surrounds the neck of the radius in a sac-like manner (*fig. 182*). This device obviously allows the radius to rotate without tearing the synovial membrane. Redundant *folds of synovial membrane* project into this joint—as they do into other joints—and assist the Haversian glands to fill the unoccupied spaces. Two of these synovial folds overlie the nonarticular indentations between the olecranon and the coronoid process; and

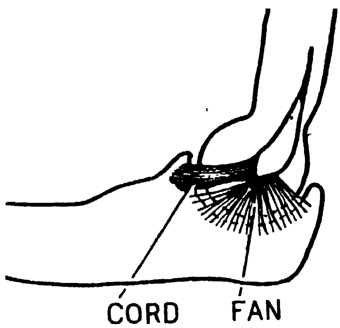


FIG. 181. Medial ligament of elbow joint.

an extensive crescentic fold occupies the angular interval between the head of the radius and the capitulum of the humerus. This fold, in fact, overlies the periphery of the upper surface of the head of the radius just as a semilunar cartilage overlies a condyle of the tibia.

Movements. *Bringing the Hand to the Mouth.* The medial lip of the trochlea of the humerus descends 5–6 mm. lower than the lateral lip; for the lower end of the humerus is oblique. On account of this obliquity you will observe that when your elbow is extended the humerus and ulna do not lie in line with one another but meet at an angle which opens laterally. This is known as *the carrying angle.*

When your elbow is fully flexed your hand is carried to your mouth. This is to be atrributed to the medial rotation of the humerus at the shoulder joint which normally accompanies flexion of the elbow, and not to the obliquity of the hinge; for it may be seen that the medial lip of the trochlea also projects forward about 5 mm. in advance of the lateral lip; therefore, though the humero-ulnar joint may be called a hinge joint, the ulna does not move on the trochlea like a door on a hinge, but rather it revolves on a cone. As a result the

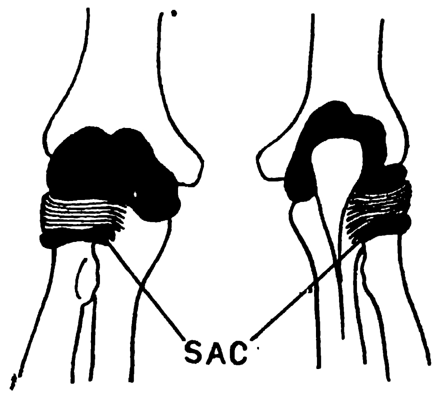


FIG. 182. Synovial capsule of elbow joint, distended.

distal end of the ulna remains lateral to the humerus in the flexed as well as in the extended position.

Muscles. Of the 3 *flexors* (*fig. 111*) of the humero-radial joint 2 act also on the radio-ulnar joints; the *Biceps* acts as a supinator and the *Pronator Teres* as a pronator; but the *Brachio-radialis* has no action on the radio-ulnar joints (Beevor). Each of the three is supplied by a different nerve.

The Brachio-radialis, though supplied by the radial nerve, is a powerful flexor of the elbow joint on account of the fact that it creeps up the humerus almost to the insertion of the Deltoid and is there-

fore far removed from the axis of the joint (*fig. 183*). Even after the musculo-

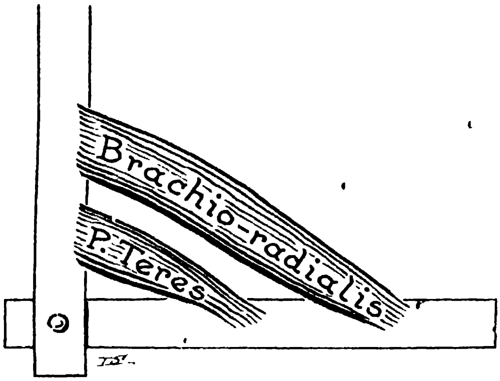


FIG. 183. As a flexor of the elbow joint, the Brachio-radialis is more advantageously situated than the Pronator Teres

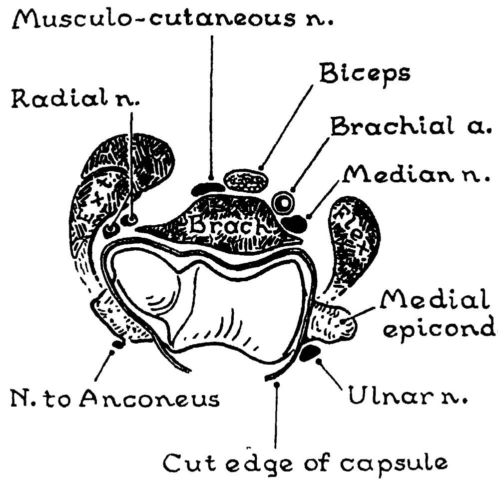


FIG. 184. Cross section through elbow joint.

TABLE 6

Muscles Acting on the Elbow Joint

SUBDIVISIONS OF THE JOINT	FLEXORS	NERVE SEGMENTS	NERVE	EXTENSORS	NERVE SEGMENTS	NERVE
Humero-ulnar	Brachialis	5, 6	Musculo-cutan.	Triceps Anconeus	7, 8	Radial Radial
Humero-radial	Biceps Brachio-radialis Pronator Teres	5, 6 (5), 6 6	Musculo-cutan. Radial Median			

cutaneous and median nerves have been divided, the Brachio-radialis is a useful flexor. But the Pronator Teres arises so close to the axis of the joint that in cases of musculo-cutaneous and radial nerve paralysis it is incapable of raising the hand to the mouth. For the same reason the muscles arising from the epicondyles have but little action on the elbow joint.

The optimum carrying position (e.g., the position in which you would instinctively carry your coat over your arm) is one in which the elbow is flexed to just less than a right angle and is semi-supinated. In this position the articular surfaces of the joint are in most perfect coaptation and the Biceps, which supinates before it flexes, comes into action.

The chief flexor of the elbow joint is the *Brachialis*. Like the *Triceps* it acts upon the humero-ulnar joint.

The common use of the *Triceps* is not so much to extent the elbow as to prevent flexion of the elbow; or to regulate flexion, as in pushing a wheelbarrow.

Flexion is more powerful than extension in the ratio of 14:9.

Relations. Muscles, nerves, and vessels (*fig. 184*). The Brachialis, though thick in the middle, is thin and attenuated at its edges. In consequence, the musculo-cutaneous nerve, which lies anterior to the middle of the muscle, is far removed from the joint; but the median and radial nerves are separated from the joint capsule merely by the thinness of

the edges of the Brachialis; the radial nerve being, as a rule, in direct contact with the capsule. The ulnar nerve is always in immediate contact with the medial ligament and it is covered by Fl. Carpi Ulnaris. The nerve to the Anconeus crosses the capsule behind the lateral epicondyle. The other muscle relations are indicated in the diagram; but, unless the points are verified in a dissected part, the diagram will be of little service.

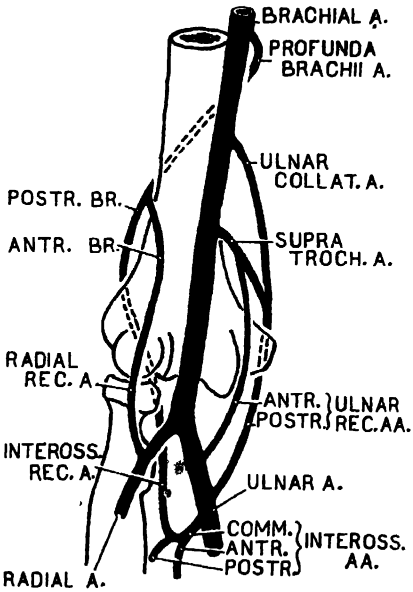


FIG. 185. Anastomoses around elbow joint.

The anastomoses around the joint are shown in the diagram (*fig. 185*). They are very ample.

The Epiphyses. *Humerus:* The epiphyseal line separating the trochlea, capitulum, and lateral epicondyle from the diaphysis runs transversely just above the articular cartilage. It is, therefore, within the synovial capsule (*fig. 186*). The medial epicondyle fuses with a spur of bone that descends from the diaphysis and separates it from the lower epiphysis proper.

Ulna: The upper epiphysis is a traction epiphysis of the Triceps. It may be a mere scale or it may include the upper third of the olecranon.

Radius: The upper epiphyseal line lies just below the head except medially where it shaves it. It is altogether intrasynovial.

Nerve Supply: musculo-cutaneous, median, ulnar, and radial; in fact, each of the five nerves shown in fig. 184, including the nerve to the Anconeus, sends twigs to the joint.

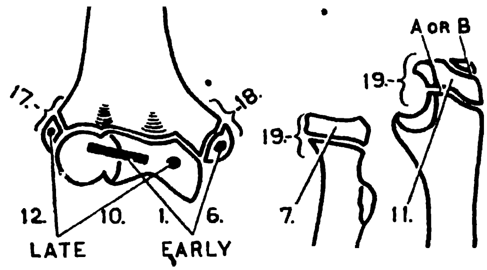


FIG. 186. Epiphyses: appearing times and fusing times are given in years.

The Radio-ulnar Joints

The two bones of the forearm are united at the proximal, "intermediate", and distal radio-ulnar joints.

The Proximal Radio-ulnar Joint was considered with the elbow joint (p. 188) because (a) they have a common synovial cavity, (b) the lateral ligament of the elbow joint is attached to the annular ligament of the radio-ulnar joint, and (c) the shape of the capitulum of the humerus is determined equally by flexion and extension of the elbow joint and by pronation and supination of the radio-ulnar joints.

The Intermediate Radio-ulnar Joint. The bodies of the radius and ulna are united to each other by three portions of fibrous tissue: (1) the oblique cord, (2) the interosseous membrane, and (3) the posterior layer of the fascia enveloping

the Pronator Quadratus. It is, therefore, a syndesmosis (syn = with; desmos = a thread).

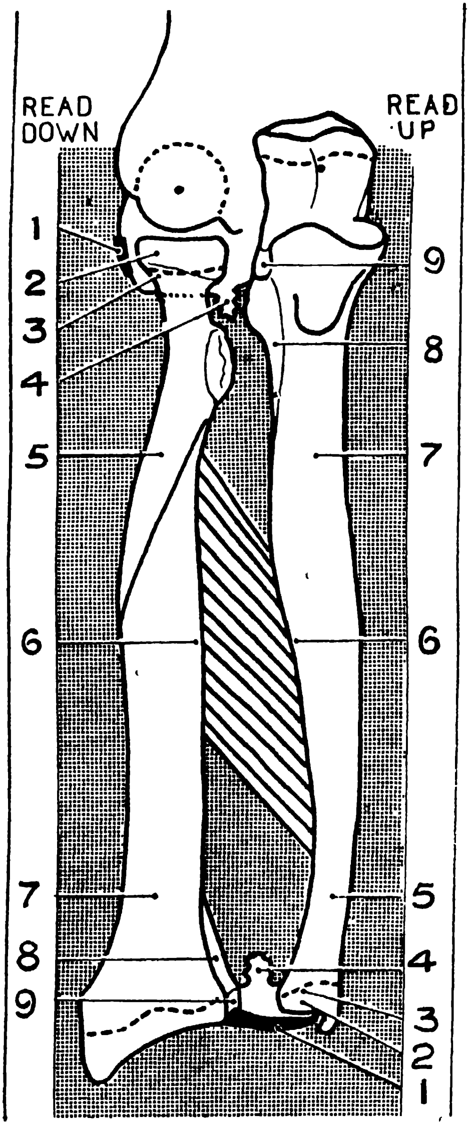


FIG. 187. Superior and inferior radio-ulnar joints compared. (1) Bond of union—annular lig. or articular disc. (2) Turned surface—disc or half disc (head). (3) Epiphyseal line enters joint cavity. (4) Sac-like protrusion of synovial membrane. (5) Bone—circular on section (6) Interosseous border—rough. (7) Bone—triangular on section. (8) Triangular area formed by splitting of interosseous border. (9) Notch—ulnar notch of radius or radial notch of ulna.

The Oblique Cord. This unimportant strand extends from the tuberosity of the ulna infero-laterally to below the tuberosity of the radius. It is regarded as a relic of the Flexor Pollicis Longus.

The Interosseous Membrane, being the medium which transfers to the ulna the force of an impact travelling up the radius, must have its fibers directed infero-medially, and must be strong. It is best marked at the middle two-fourths of both bones. It is responsible for the roughness of their interosseous borders. It is taut when the forearm is midway between pronation and supination.

The Posterior Layer of the Fascia enveloping the Pronator Quadratus is much thicker than the anterior layer, and it is continuous above with the interosseous membrane. Below, it follows the hinder of the two lines into which the interosseous border of the radius splits above the ulnar notch. It is composed of interlacing areolar tissue fibers and has not much strength.

The Distal Radio-ulnar Joint in some degree duplicates the design of the proximal joint (*fig. 187*). Thus, (a) the head of the ulna forms half a cup-shaped disc; (b) its surface and its margin are articular; (c) it is only slightly, if at all, weight-bearing; (d) the epiphyseal line enters the joint; (e) the ulnar notch of the radius rotates around it. (f) A sac-like redundancy of synovial membrane extends for a quarter of an inch above the joint to allow of rotation.

In contrast, note (a) that the radius does not throw an annular ligament around the head of the ulna, but it is firmly united to the ulna by a triangular plate of fibro-cartilage, the *articular disc*; and (b) that though the proximal radio-ulnar joint has a common synovial cavity with the elbow joint, the distal joint is excluded from the wrist joint.

The under surface of the semicircular *head of the ulna* has a semilunar facet for the articular disc to play on, and within the concavity of the semilune, at the root of the styloid process, there is a fovea or pit To this pit the apex of the articular disc, which necessarily is pliable, is attached by fibrous (ligamentous) tissue; the base of the disc is attached to the lower margin of the ulnar notch of the radius. The anterior and posterior ligaments of the joint are lax to allow the radius to rotate on the ulna.

RELATIONS. In front lies the Flexor Digitorum Profundus; behind lies the Extensor Digiti Minimi.

THE LOWER EPIPHYSEAL PLATES of the radius and ulna lie on the same plane and cut into the distal radio-ulnar joint; that of the radius passes through the dorsal radial tubercle. The attachment of the Brachio-radialis is to the diaphysis.

The radial epiphysis begins to ossify at (1) 2 years; and unites with the diaphysis at (18) 19 years.

The ulnar epiphysis begins to ossify at (5) 6 years; and unites with the diaphysis at (17) 19 years.

MOVEMENTS. The axis on which the radius revolves about the ulna during pronation and supination, passes through the capitulum of the humerus and the pit at the lower end of the ulna to which the articular disc is attached (*fig. 187*). The joint may be called a lateral hinge joint or a pivot or a trochoid joint. The only other joint in the body that in any way resembles it is the joint where the dens of the axis rotates in a ring formed by the atlas and its transverse ligament.

The value of the radio-ulnar joints depends upon the fact that the hand rotates with the radius following its excursions.

OBSERVATION. When your elbow is flexed to a right angle and applied closely to the side of your body, so as to eliminate shoulder movements, your hand can be rotated through nearly two right angles. When your shoulder is abducted and your elbow extended, as in fencing, your hand can be rotated through nearly three right angles. The movements of pronation and supination of the radio-ulnar joints under these circumstances augment the axial rotation of the shoulder joint.

NERVE SUPPLY: the proximal joint by the nerves to the lateral part of the elbow joint; the distal joint by the anterior and posterior interosseous nn.

TABLE 7

Muscles Acting upon the Radio-ulnar Joints and Their Nerves and Nerve Segments

PRONATORS	SEGMENT	NERVE	SUPINATORS	SEGMENT	NERVE
Pronator Quadratus	(7), 8, 1	Anterior Interosseous	Supinator	5, 6	Posterior Interosseous
Pronator Teres	6	Median	Biceps	5, 6	Musculo-cutaneous
Fl. Carpi Radialis	6	Median	2* dorsal muscles of the thumb	(6), 7, (8)	Posterior Interosseous

* The Ex. Poll. Brevis arises from the radius and therefore cannot assist in rotation.

The Wrist Joint or Radio-carpal Joint.

OBSERVATIONS You can easily observe on your own limb that the movements permitted at the radio-carpal joint are: flexion or palmar-flexion, extension or dorsi-flexion, adduction or ulnar-flexion, and abduction or radial-flexion. These together comprise the movement of circumduction. The articulation is, therefore, a condyloid or knuckle-like joint;

i.e., the same movements are permitted as at the knuckles.

Flexion at the radio-carpal joint would seem to be of greater range than extension, but this is a deception: extension is here more free than flexion. It is to the transverse carpal joint that the greater part of the flexion attributed to the wrist joint is in reality due. Abduction is clearly more restricted than adduction, owing to the fact that the styloid process of the radius descends further than the styloid process of the ulna.

You have here to deal not with a "ball" and socket but with an "ovoid" and socket, for the articular surfaces are not circular in outline but ellipsoidal, the wrist being compressed from before backwards (*fig. 188*). Axial rotation with ellipsoidal surfaces would obviously result in dislocation; so, it is not permitted at the radio-carpal joint. But, axial rotation—or rather pronation and supination—occurs at the radio-ulnar joints. So, the radio-carpal joint and the radio-ulnar joints together duplicate the movements of the shoulder joint; the one allowing circumduction; the other rotation—and all is in the interest of the hand.

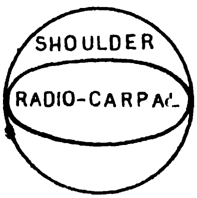


FIG. 188. Circle versus ellipse.

Joint Surfaces. The socket is formed by the lower articular surface of the radius plus the articular disc. The egg-shaped or ellipsoidal convex surface is formed by the proximal articular surfaces of the scaphoid, lunate, and triquetrum, plus the interosseous ligaments binding these three bones together. Figure 189 shows that the proximal bearing surfaces of the scaphoid and lunate are approximately equal in extent, and that that of the triquetrum is almost negligibly small. Figure 123 shows that, with the hand at rest, the facet on the upper surface of the triquetrum is in contact with the medial ligament of the wrist, and that the scaphoid and lunate alone transmit impacts from the carpus to the forearm. Only in adduction does the triquetrum come into contact with the socket, and even then it is only with the part formed by the triangular articular disc. When the radius and articular disc rotate about the ulna, they carry the hand with them. This is possible because the carpal bones do not articulate with the ulna but with the disc which excludes the ulna from the wrist joint. The articulation is, therefore, called radio-carpal and not radio-ulnocarpal (*fig. 190*).

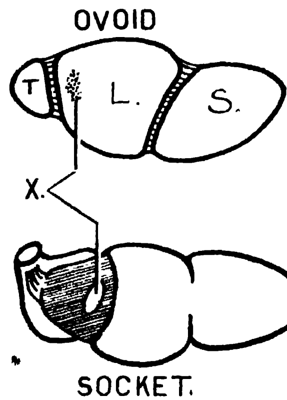


FIG. 189. "Ovoid" and socket of wrist joint. "X" marks the sites at which the disc is sometimes perforated and the lunate softened.

It commonly happens that the articular disc and also both interosseous ligaments that take part in the "ovoid and socket" of the wrist joint, shown in fig. 189, are perforated. In consequence, the distal radio-ulnar joint is brought into communication with the wrist joint, and the wrist joint with the intercarpal joints. The perforation in the disc begins as an antero-posterior fissure, and in time it be-

comes a round hole. Further, the cartilage of the lunate opposite the hole is usually softened and unhealthy. To determine in a dissected specimen whether the interosseous ligaments are perforated or not, grasp the scaphoid, lunate, and triquetrum individually, and move them backwards and forwards on each other. The state of affairs will then reveal itself.

Ligaments. The fibers of the *anterior and posterior radio-carpal ligaments* are so disposed that during pronation and supination of the forearm the radius shall drag the carpal bones after it. They, therefore, pass obliquely infero-medially from the front and back of the lower end of the radius to the front and back of the proximal row of carpal bones and to the capitate (*fig. 191*).

The extensor retinaculum (dorsal carpal lig.), actually a thickened portion of the deep fascia (p. 167), may be regarded as a superficial layer of the posterior radio-carpal ligament that has been detached through the interposition of the extensor tendons.

The lateral and medial ligaments (radial and ulnar collateral ligs.) extend from the tips of the styloid processes of the radius and ulna to the scaphoid and triquetrum respectively.

Muscles. The muscles acting on the radio-carpal joint and their nerve segments are given in Table 8.

Actions. The flexors and extensors of the joint are indicated in figure 192.

The Fl. Carpi Ulnaris, which is inserted into the front of the base of metacarpal V via the piso-metacarpal ligament (and into the hook of the hamate via the piso-hamate ligament), has a mechanical advantage over the Ex. Carpi Ulnaris, which is inserted into the tubercle on the side of the base of the same metacarpal, because in the pisiform it possesses a raised moving pulley which advances it in front of the transverse axis of the joint.

The Fl. Carpi Radialis, inserted into the fronts of the bases of metacarpals II and III, has a mechanical advantage over the Ex. Carpi Radiales (Longus et Brevis), which are inserted into the dorsal aspects of the bases of the same two metacarpals because prior to occupying the vertical groove on the trapezium it crosses the tubercle of the scaphoid which acts as a raised though fixed pulley,

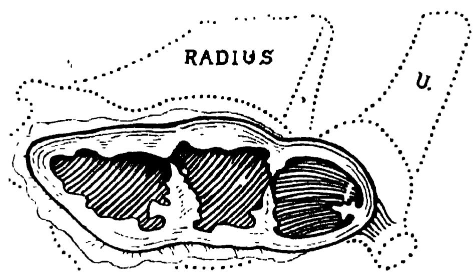


FIG. 190. Socket for proximal row of carpals. Note the synovial fringes.

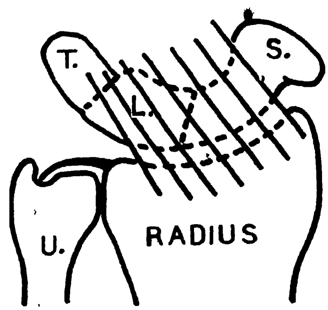


FIG. 191. Anterior (or posterior) radio-carpal ligament.

which advances it well in front of the joint.

The Palmaris Longus passes in front of the flexor retinaculum and is therefore also far in advance of the transverse axis of the joint. It has no pulley.

The three important flexors are, therefore, more advantageously situated than the three important extensors which play in grooves on the lower ends of the bones of the forearm. Flexion is more power-

ful than extension in the ratio of 13:5 (Fick).

The tendon of the *Abductor Pollicis Longus* is inserted in front of the transverse axis of the joint and therefore acts as a flexor. It has the power to raise the hand of a horizontally held limb

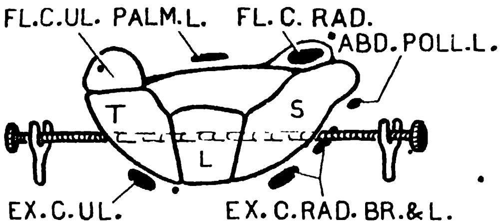


FIG. 192. The flexors and extensors of the wrist joint.

fibers here or distally. In allotting the tendons at the back of the wrist to their appointed places, it is perhaps easiest to dispose first of the 3 thumb muscles, because they are conspicuous where they bound the snuff-box and they can be traced proximally. (1) *The Ex. Pollicis Longus* lies in a narrow groove medial to its pulley, the easily palpated dorsal radial tubercle. (2) the *Abd. Pollicis Longus and Ex. Pollicis Brevis* lie in a broad shallow groove that completely covers the side of the styloid process of the radius. (3) the *Ex. Carpi Radialis Longus and Brevis* groove the remaining part of the radius lateral to the dorsal tubercle. They can be felt in the snuff-

TABLE 8

Muscles Acting on the Radio-carpal Joint and Their Nerve Segments

FLEXION		EXTENSION		ABDUCTION		ADDUCTION	
Fl. C. Ulnaris	8, 1	Ex. C. Ulnaris	7	Ex. C. Radialis Longus	6, 7	Ex. C. Ulnaris	7
Fl. C. Radialis	6	Ex C. Radialis Longus	6, 7	Ex. C. Radialis Brevis	6, 7, 8	Fl. C. Ulnaris	8, 1
Palm. Longus.	7, 8, 1	Ex. C. Radialis Brevis	7	Fl. C. Radialis	6		
Abd. Poll. Long.	7			3 dorsal tendons of the thumb	7		

even when the other flexors are paralyzed. It is also an abductor of the wrist.

The Relations of the joint are: the *tendons* on the front and back of the wrist; the *radial artery*, which after passing deep to the Abd. Pollicis Longus and Ex. Pollicis Brevis crosses the lateral ligament; the *dorsal* (*cutaneous*) *branch* of the ulnar nerve, which after passing deep to the Fl. Carpi Ulnaris crosses the medial ligament; the anterior and posterior *interosseous vessels and nerves* and the anterior and posterior *carpal networks;* more remotely are the *ulnar vessels and nerve;* and the *median nerve.*

Tendons at the Back of the Wrist (*fig. 193*). Of course, there can be no fleshy

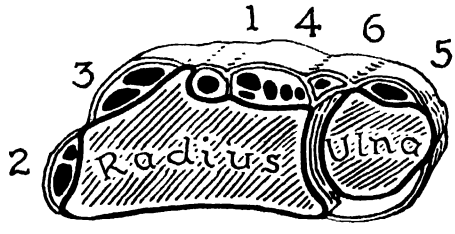


FIG. 193. Tendons at back of wrist (for description see text).

box when the fist is clenched. (4) the *Common Extensor tendons* and the *Ex. Indicis Proprius* groove the remaining part of the radius medial to the Ex. Pollicis Longus. (5) the *Ex. Carpi Ulnaris* fills the groove between the head and styloid process of the ulna. (6) the

Ex. Digiti V Proprius lies behind the inferior radio-ulnar joint. The Ex. Digiti V Proprius is, therefore, on the medial side of the common extensor tendon of the little finger: and it may be noted that the Ex. Indicis Proprius lies on the medial side of the common extensor tendon of the index finger.

NERVE SUPPLY: Anterior interosseous branch of the median, posterior interosseous branch of the radial, and deep palmar and dorsal cutaneous branches of the ulnar.

The Intercarpal and Carpo-metacarpal Joints are described with the carpal bones on pages 139–140.

NERVE SUPPLY: The same as for the radio-carpal joint.

The Intermetacarpal Joints.

BASES. The opposed sides of the bases of metacarpals 2 and 3; 3 and 4; and 4 and 5 are contiguous. They have articular facets and their three joint cavities are continuous with the cavities of the carpo-metacarpal joints.

HEADS. The opposed sides of the heads of these metacarpals are overlaid by collateral ligaments (*fig. 126*). Hence, they themselves are non-articular, but the contiguous collateral ligaments are separated by *bursae*, which play the part of joint cavities, necessary to the pliability of the hand at the knuckles. The same arrangement obtains in the foot.

The Metacarpo-phalangeal and Interphalangeal Joints are described with the metacarpal bones and phalanges on pages 142–143.

NERVE SUPPLY: "It is quite evident from clinical observations that the digital nerves are the only important source of sensory fibres to the articulations of the digits." These are derived from the median, ulnar, and radial nerves. There is some variation in the number of joints each supplies, and this corresponds with the variations in the cutaneous distribution of these branches (*fig. 95*). (Stopford.)

Movements of the Fingers. The Flexor Digitorum Profundus flexes the distal interphalangeal joints; the Flexor Digitorum Sublimis flexes the proximal interphalangeal joints; and continuing to act, these two muscles flex the metacarpophalangeal, transverse carpal, and radiocarpal (wrist) joints; that is, they close the hand and curl it up. When doing so, they draw together (adduct) the fingers.

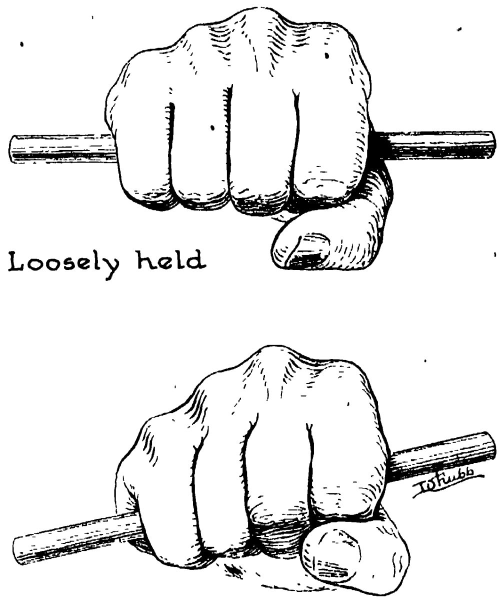


FIG. 191. Because the 4th and 5th carpometacarpal joints are hinge joints (pp. 137, 138), the grip on a rod is more secure.

Usually, when the hand is closed, the action of the Profundus and Sublimis on the wrist is opposed by the three extensors of the wrist (see table 8) which, acting as synergists, steady the wrist. If it is

desired to flex the wrist with force or against resistance, the four flexors of the wrist (see table 8) are also called into action. Verify this by closing the hand, palm upwards, and flexing the wrist; then, keeping it flexed, place the knuckles of the proximal phalanges under the edge of a table, and observe that the wrist flexors spring into prominence the moment the least resistance is encountered.

The Ex. Digitorum Communis, Ex. Indicis, and Ex. Digiti V extend the metacarpo-phalangeal joints, and when so-doing spread (abduct) the fingers. Their power to extend the interphalangeal joints is much restricted by their attachments at the bases of the proximal phalanges. The interphalangeal joints are extended by the Lumbricales, Interossei, and Abd. Digiti V through their attachments to the dorsal expansions.

The Interossei and Abd. Digiti V abduct and adduct the fingers at the metacarpo-phalangeal joints; this they can do while the palm lies flat on a table. Also, they can move each finger separately. These peculiarities distinguish Interosseous action (which is solely mediated by the ulnar nerve) from the abductor action of the long Extensors (mediated solely by the radial nerve) and adductor action of the long Flexors (mediated chiefly by the median), as stated above.

The Lumbricales, Interossei, and Abd. Digiti V flex the metacarpo-phalangeal joints of the fingers but extend the interphalangeal joints, as in making the upstroke in writing.

The 4 flexors of the wrist (see table 8) acting as synergists, steady the wrist when the extensors of the fingers are in action; similarly, the 3 extensors of the wrist act synergically when the flexors of the fingers are in action.

You cannot fully flex your wrist while the hand is closed, but only when the fingers are extended; this is owing to the relative shortness of the extensor tendons. Similarly, you cannot fully extend your wrist while the fingers are extended; this is owing to the relative shortness of the flexor tendons.

Movements at the Carpo-Metacarpal Joints. The first of these joints (i.e., that of the thumb) is saddle-shaped; here flexion-extension, adduction-abduction, and modified rotation (whereby the pad of the thumb is brought to face that of a finger in opposition) take place. The movement of opposition is described on page 150. The reverse movement of *reposition* is carried out by the 3 dorsal muscles of the thumb: Abd. Pollicis Longus, Ex. Pollicis Brevis, and Ex. Pollicis Longus. The 2nd and 3rd joints are practically immobile. The 4th and 5th, have slight hinge movements; the 5th especially can be flexed, and it is the forward or flexor movement of the 5th metacarpal that largely prevents a cylindrical object, such as the handle of a wheel-barrow or a garden rake, from slipping through the closed hand (*fig. 194*); similarly, it helps when climbing or pulling a rope. The muscles here concerned are the three muscles of the hypothenar eminence and the long flexors.

TABLE 9

Table of Appearance and Fusion Times of Epiphyses, Including Primary Centers for Carpus and Tarsus, in Years Unless Otherwise Stated.

	APPEARS	FUSES	
Scapula Acromion	15	19	
Coracoid	1	15*	
Sub-coracoid	10		
Inf. Angle	15	22	
Vertebral Border	15	22	
Clavicle Sternal end	18+	22+	
Humerus Head	Birth	6} 19*	← with shaft →
Greater Tuberosity	3		
Lesser Tuberosity	5		
Medial Epicondyle	6	18	
Lateral Epicondyle	12	15} 17	
Capitulum	1		
Trochlea	10		
Radius Upper end	7	19	
Lower end	1	19*	
Ulna Upper end	11	19	
Lower end	6	19*	
Scaphoid	6		
Lunate	5		
Triquetrum	4		
Hamate	½		
Capitate	½		
Trapezoid	6		
Trapezium	6		
Pisiform	12		
1st Metacarpal base	−3	19	
2nd–5th Metacarpal heads	−3	19	
Thumb, Proximal Phalanx base	2	18	
Distal Phalanx base	−3	18	
2nd–5th Fingers, Proximal Phalanx base	2	18	
Middle Phalanx base	−3	18	
Distal Phalanx base	−3	18	
Sesamoids of thumb	−13		
Hip bone, three primary parts		16*	
Ischium and Pubis		9	
Ischial tuberosity	19	20	
Iliac crest	16	22	
Femur Head	1	18*	
Greater Trochanter	−5	18*	
Lesser Trochanter	−14	18*	
Lower end	Birth	19*	
Tibia Upper end	Birth	19	
Lower end	2	18	
Fibula Upper end	5	19	
Lower end	2	18	
Calcaneum‡	−30 week		
Tuberosity	11	17	
Talus‡	−30 week		
Navicular	3		
Cuboid ‡	+30 week		
1st Cuneiform	3		
2nd Cuneiform	−4		
3rd Cuneiform	1		
Great Toe Metatarsal base	−3	18	
2nd–5th Metatarsal heads	−5	18	
Great Toe, Proximal Phalanx base	−4	19	
Distal Phalanx base	2	19	
2nd–5th Toes, Proximal Phalanx base	−5	19	
Middle Phalanx base	−5	19	
Distal Phalanx base	−5	19	
Patella	−5		
Sesamoids of great toe	−12		
Rib Head	15	22+	
Tubercle	18	As it ossifies	

Since the student will be concerned with the age periods at which he may reasonably be sure that fusion is complete, the *latest* times of fusion are given. Female bones fuse distinctly earlier.

* Asterisks denote times that are found to be quite constant. The table is a compilation from several authorities and is based on X-ray findings. It has been deemed advisable to give definite ages rather than a spread. Figures denote years unless otherwise stated.

+ = a later tendency. − = an earlier tendency. ‡ = before birth.

SECTION III

THE ABDOMEN

CHAPTER 8

The abdomen is the region of the trunk below the diaphragm. Its walls enclose and protect two hollow, tubular systems:

1. The gastro-intestinal canal and its two offshoots; the liver and pancreas, together with the spleen; and,
2. The greater part of the uro-genital system.

The different parts of the gastro-intestinal canal, being at one time full and at another time empty, require space in which to dilate, contract, and move about. This is afforded them by what is virtually an enormous bursa, called the *peritoneal cavity,* into which they project freely.

THE ANTERIOR ABDOMINAL WALL

When the physician examines a patient's abdomen he inspects and palpates the anterior abdominal wall. When the surgeon operates on the abdomen he cuts through the anterior abdominal wall. It is well, therefore, to have a knowledge of its structure.

Boundaries. The anterior abdominal wall is bounded above by the xiphoid process and the costal cartilages—not of the lower six ribs of each side, because the 11th and 12th costal arches are not long enough to reach the front, but—of the 7th, 8th, 9th and 10th (*fig. 195*). It is bounded below on each side by the portion of the iliac crest lying between the tubercle and the anterior superior spine, Poupart's inguinal ligament, the pubic tubercle, the pubic crest, and the upper end of the pubic symphysis.

The xiphoid process, note, lies at the bottom of the depression between the 7th costal cartilages. It varies in length and in shape. Its edges and tip afford attachment for the aponeurosis of the

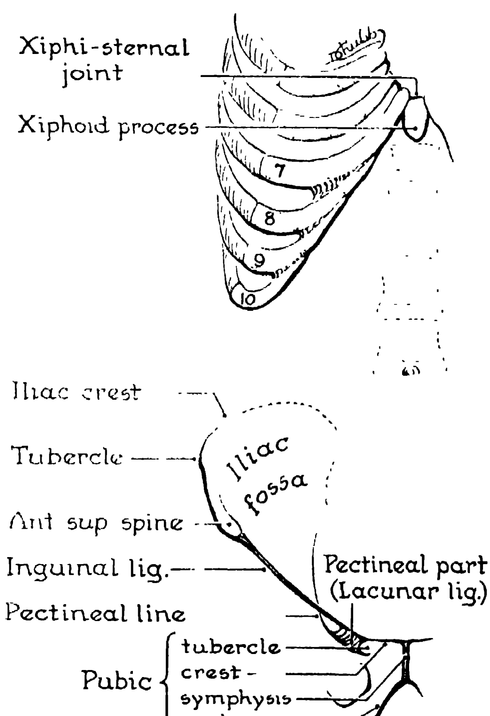


FIG. 195. Boundaries of the anterior abdominal wall.

Transversus Abdominis; so, they are attenuated and not easily palpated, and the attempt to do so causes discomfort. Hence, the easily palpated lower end of the body of the sternum, at the xiphisternal joint, is preferred as a landmark.

The Superficial Fascia covering the lower part of the abdominal wall is disposed in two easily separable layers: (1) an *adipose layer*, such as clothes the body generally, the fascia of Camper; and (2) a deeper *membranous layer* devoid of fat, the fascia of Scarpa. It is important to note that, if a horizontal incision be made through the fatty and membranous layers, the finger can be passed downwards in a pocket between the membranous layer and the underlying aponeurosis of the External Oblique. In the region lateral to the pubic tubercle the finger will be arrested by the attachment of the membranous layer to the fascia lata (i.e., deep fascia of the thigh) a finger's breadth below the inguinal ligament (*fig. 196*); medial to the pubic tubercle it can be passed downwards into the scrotum, for here the membranous layer is attached to the fascia lata along the lateral border of the spermatic cord. In the median plane the finger is arrested by a mass of fibro-elastic tissue, *suspensory ligament of the penis* and scrotum, which is attached above to the symphysis pubis and lower part of the linea alba; below, it forms a sling for the penis and sends fibers to end in the scrotum.

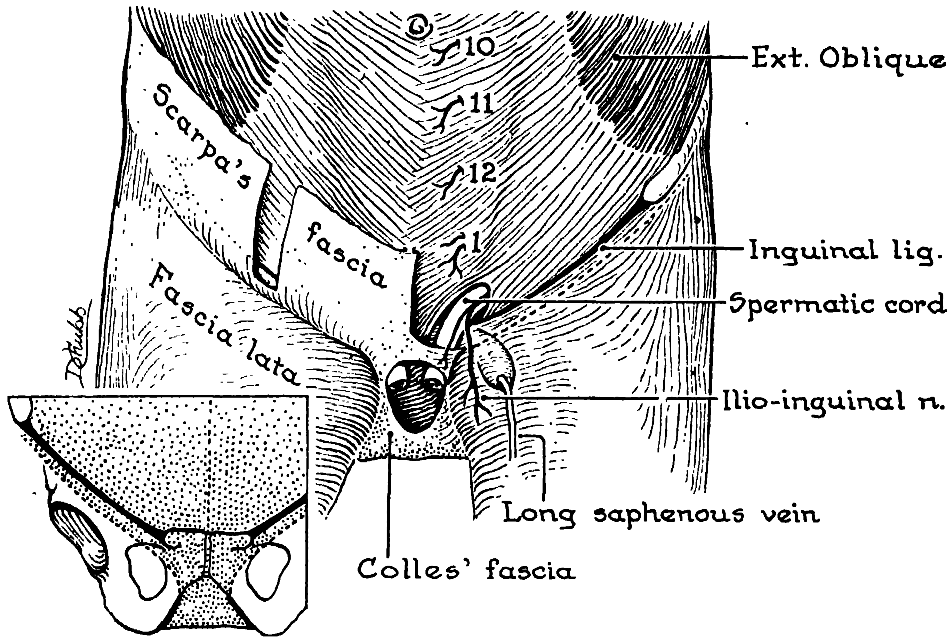


FIG. 196. The fasciae of Scarpa and Colles. (The penis and scrotum are cut away and the spermatic cords are cut across.) The inset shows the attachment of Colles' fascia to the pubic bone.

The cutaneous vessels and nerves lie in the superficial fatty layer of Camper (*see pp. 204–206*).

Deep Fascia, such as is wrapped around the limbs, is made of the same stuff as tendons and ligaments, and is practically inelastic. There can, therefore, be no deep fascia—in this sense—enveloping the abdomen and thorax. If there were, one would look forward with apprehension rather than with pleasure to the next meal and respiration would be impossible. All muscles, though, are surrounded with the more or less areolar tissue in which

they developed; for example, the Pectoralis Major, Latissimus Dorsi, Trapezius, Serratus Anterior, and the three flat muscles of the abdomen are covered with loose areolar tissue on both surfaces – but this is not deep fascia as usually understood.

Axiom. The areolar tissue found between muscles affords them freedom of movement, and its quantity varies with their range of independent contraction.

Muscles. On each side of the anterior abdominal wall are the following muscles:

Rectus Abdominis, and Pyramidalis, and

Three flat muscles:
- Obliquus Externus Abdominis
- Obliquus Internus Abdominis
- Transversus Abdominis

The Rectus Abdominis and Its Sheath. The Rectus Abdominis is a long strap-like muscle. It acts at right angles to the 3 flat muscles and it obtains a certain freedom to contract by lying within a sheath. The sheath is formed by the splitting of the aponeurosis of the Internal Oblique into an anterior and a posterior lamella. The anterior lamella is reinforced by the aponeurosis of the External Oblique; the posterior lamella by the aponeurosis of the Transversus (*fig. 198*). When the anterior wall of the sheath is incised longitudinally, it is found that transverse *fibrous intersections* in the Rectus, indicative of its segmental origin, adhere to the anterior wall of its sheath at the levels of the umbilicus and xiphoid process, and midway between these two levels (*fig. 197*).

The Rectus Abdominis is attached horizontally above to the front of the xiphoid process and to the cartilages of the 7th, 6th, and 5th ribs. This upper attachment is three times as broad (3 inches) as the lower attachment to the front of the symphysis and body of pubis just below the crest. As would be expected, the thoracic attachment is fleshy; the pubic attachment is tendinous.

Surface Anatomy. The lateral border of the Rectus curves from the pubic tubercle, across the middle point of the line joining the anterior superior spine to the umbilicus, across the chest margin where, three inches from the middle line,

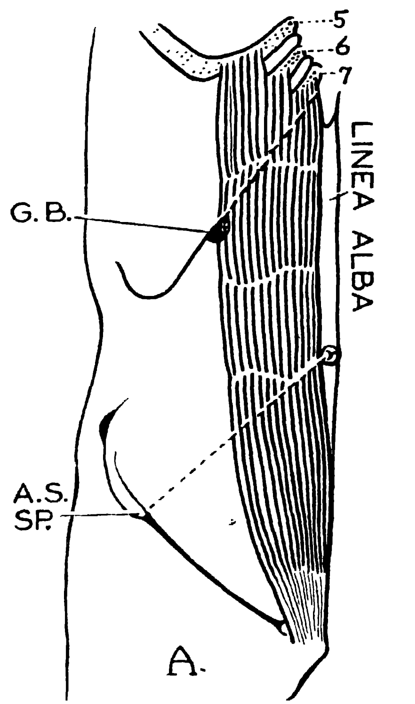


FIG. 197. (A) The Rectus Abdominis. G.B. = gall bladder.

it overlies the tip of the 9th costal cartilage, and on to where the 5th cartilage and rib meet. Its medial border is separated from that of its fellow by the *linea alba*; that is, the line extending between the xiphoid process and the symphysis pubis in which the aponeurotic fibers of the three flat muscles decussate. Below the umbilicus the linea alba is truly linear, the two Recti being practically in

contact with one another; but above the umbilicus it forms a band or "tinea" half-an-inch wide.

Small gaps may be present between the decussating fibers of the linea alba through which herniae of extraperitoneal fat protrude.

THE POSTERIOR WALL OF THE RECTUS SHEATH. At four different levels four different tissues, lie in contact with the posterior surface of the Rectus (*fig. 198*). From below upwards they are: (a) areolar tissue, (b) fibrous tissue, (c) muscle, and (d) cartilage. First, consider level b:

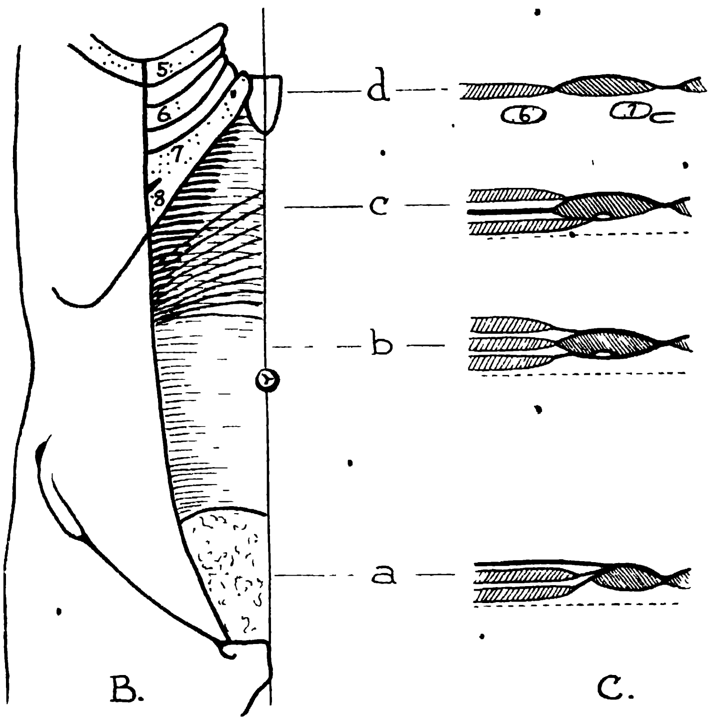


FIG. 198. (B) The posterior wall of the Rectus sheath. (C) Transverse sections of the sheath at four levels.

Actions. When, on awakening in the morning, one rises from the recumbent to the sitting posture, the Sterno-mastoids raise the head and indirectly flex the cervical vertebrae; the Recti Abdominis approximate the thorax and pelvis and indirectly flex the thoracic and lumbar vertebrae; and the Ilio-psoas flex the lumbar vertebrae and the hip joints.

The Recti can by contracting break the force of a blow and so protect the abdominal viscera from injury.

here the posterior layer of the aponeurosis of the Internal Oblique, reinforced by the aponeurosis of the Transversus, extends from about three inches above the pubis to about three inches below the xiphi-sternal junction, and constitutes the posterior layer of the true or fibrous sheath of the Rectus; its lower free edge is known as the *arcuate line* (semicircular line). Below this, (level a) the aponeuroses of all three flat muscles pass in front of the Rectus, leaving its lowest

three inches in contact posteriorly with the areolar fascia transversalis. Above this, (level c) the Internal Oblique does not extend, with the result that the three inches of the Rectus just below the body of the sternum come into contact with practically the whole breadth of the narrow upper end of the Transversus including its fleshy costal origin. This fleshy origin is seen shining through the film of areolar tissue that covers it. Above the chest margin, (level d) the

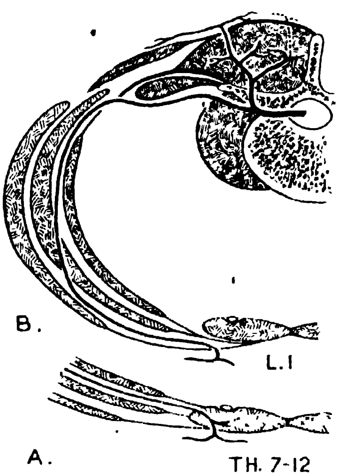


FIG. 199. The course of an anterior nerve ramus in the abdominal wall. (a) Lower thoracic. (b) 1st lumbar.

Rectus lies in front of cartilages (9), 8, 7, 6, (5). Because the External Oblique alone of the three flat muscles extends above the chest margin, its aponeurosis alone forms the front of the Rectus sheath at level d. And, from its upper border the Pectoralis Major partly arises.

THE ANTERIOR WALL OF THE RECTUS SHEATH. Four different tissues clothe the Rectus behind; but only one tissue clothes it in front, and it is aponeurotic or fibrous. This anterior fibrous wall of the Rectus sheath has, however, three different thicknesses—above the costal margin it is formed by External Oblique only; in the intermediate part by External Oblique and half the Internal Oblique; in its lowest three inches or so by all three flat muscles.

THE PYRAMIDALIS is a triangular muscle that lies in front of the lower part of the Rectus Abdominis. It arises from the front of the body of the pubis below the crest, and is inserted into the linea alba below the umbilicus; but it is commonly absent. A twig from Th. 12 nerve supplies it.

The Contents of the Rectus Sheath:

Muscles: Rectus Abdominis & Pyramidalis.

Nerves: anterior branches of Th. 7-12.

Vessels: superior and inferior epigastric.

Nerves. THE ANTERIOR RAMI of the *lower six thoracic nerves* run between the Internal Oblique and the Transversus and they are guided by these muscles to where their aponeuroses blend behind the lateral margin of the Rectus (*fig. 199*). Thereupon, they pierce every structure intervening between them and the skin (i.e., the posterior lamella of the Internal Oblique, the Rectus, the anterior wall of the Rectus sheath) and ramify in the subcutaneous tissues, as anterior cutaneous nerves.

The anterior ramus of the *1st lumbar nerve* divides into two: the *ilio-hypogastric* and *ilio-inguinal*. Medial to the anterior superior spine these 2 nerves run between the Internal and External Obliques, and they are guided by these muscles to the front of the Rectus; hence, they require to pierce only the External Oblique aponeurosis, or its tubular prolongation, the *external spermatic fascia*, to become cutaneous. The ilio-hypogastric nerve pierces the aponeurosis an inch or so above the superficial inguinal ring; the ilio-inguinal nerve passes through the ring and pierces the external spermatic fascia.

Distribution (*fig. 200*). Of these nerves, the 10th supplies the skin around the umbilicus, leaving three nerves (9, 8 and 7) to supply the region above the umbilicus, and three (11, 12 and 1) to supply the region below the umbilicus. Indeed, the ilio-inguinal nerve supplies the skin at the root of the penis, upper part of the scrotum, and adjacent part of the thigh.

While these nerves (Th. 7—L.1) are running between the Internal Oblique and the Transversus, they supply them, 12 and 1 being the most important because they control the most vital part of the abdominal wall (*fig. 202*).

Those nerves that pierce the Rectus (7 to 12, but not 1) also supply it; and to sever any one of them results in paralysis of that segment of the Rectus for which it is responsible, with resulting weakness of the abdominal wall.

THE LATERAL CUTANEOUS BRANCHES of the lower six thoracic and first lumbar anterior rami arise and become cutaneous in front of the mid-lateral line, mid-axillary line, or half way around the body—whichever you prefer—and so are in line with the intercosto-brachial and other lateral cutaneous nerves (*fig. 68*). They appear between the digitations of the Serratus Anterior or External Oblique according to their level. The lateral cutaneous branches of segments Th. 7, 8, 9, 10, and 11 send: (a) branches forwards as far as the lateral border of the Rectus where they meet the anterior cutaneous branches of their respective segments—these lateral cutaneous branches supply the External Oblique—and (b) branches backwards across the Latissimus Dorsi for a short distance. The lateral cutaneous branches of segments Th. 12 and L. 1 cross the iliac crest in front of the tubercle and behind it respectively and ramify above the level of the trochanter. They are generally referred to as the *iliac branches of the subcostal and ilio-hypogastric nerves.*

Vessels (*fig. 200*). *The Superior Epigastric Artery* enters the Rectus sheath behind the 7th costal cartilage and anastomoses with the *Inferior Epigastric Artery* which enters the Rectus sheath in front of the arcuate line. Thus, vessels to the upper and lower limbs are brought

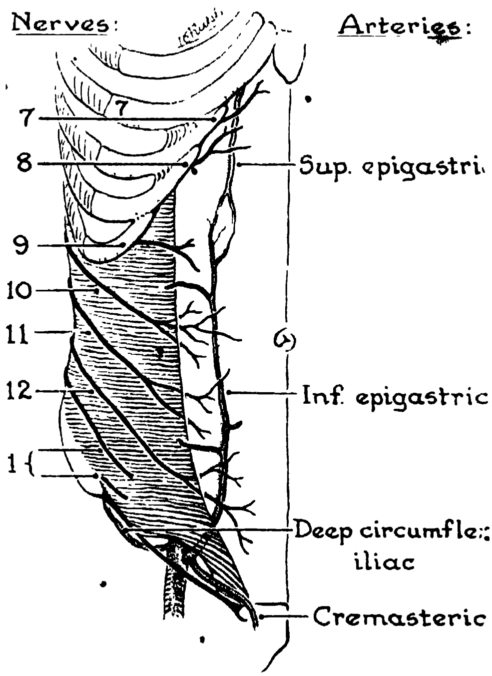


FIG. 200. The nerves and arteries within the rectus sheath.

into communication with each other—for the superior epigastric artery is one of the two terminal branches of the internal mammary branch of the subclavian artery, and the inferior epigastric artery is one of the two collateral branches of the external iliac artery. Being the only two arteries in this region, the two epigastric arteries have of necessity to supply everything in the region.

Branches. Their branches accordingly are *cutaneous, muscular,* and *anastomotic.*

The inferior epigastric artery has in addition two branches of some importance: (a) a *cremasteric branch* (ext. spermatic a.) which supplies the coverings of the spermatic cord and anastomoses with the testicular artery (int. spermatic a.), and (b) a *pubic branch* which passes to the back of the pubic bone (see *p. 348*).

The lateral border of the Rectus is a nearly bloodless line, because very few branches of the epigastric arteries cross it and anastomose with the intercostal and lumbar arteries.

OTHER VESSELS IN THE ANTERIOR ABDOMINAL WALL: *Intercostal and Lumbar Arteries* accompany nerves T. 11, 12, and L. 1 and their lateral branches.

The Deep Circumflex Iliac Artery ramifies between the Internal Oblique and the Transversus (p. 214).

The Three Superficial Inguinal Arteries spring from the femoral artery and run in the superficial fascia, thus: (a) the *superficial epigastric a.* runs towards the navel; (b) the *superficial external pudendal a.* crosses in front of the spermatic cord to supply the scrotal wall, and (c) the *superficial circumflex iliac a.* runs below the lateral half of the inguinal ligament

The Three Superficial Inguinal Veins end in the long saphenous vein.

The Superficial Lymph Vessels of the anterior abdominal wall above the level of the navel pass to the axillary glands; those below to the inguinal glands, situated immediately below the attachment of the membranous layer of Scarpa to the fascia lata.

The Three Flat Muscles of the Abdomen. The Obliquus Externus, the Obliquus Internus, and the Transversus are the prototype of "three ply" wood, for the general directions of their fibers are respectively downwards and medially, upwards and medially, and transversely. Though the majority of the fibers of the three muscles take these *three general directions*, you will find that below the level of the anterior superior iliac spine all the fibers of all three muscles take *one particular direction*—downwards, forwards, and medially. These lower fibers, though in the minority, happen to be the most important fibers of the muscles; and, their attachments are complicated by the fact that before birth the testis in the male (round ligament in the female) descended from the abdomen into the scrotum (labium majus in the female) carrying before it a covering from each of the three flat muscles.

The Obliquus Externus Abdominis arises from the lower eight ribs a hand's breadth from the costal margin. (The 11th and 12th ribs, being very short, it arises from the ends of their cartilages.) The origin is by means of fleshy digitations that interlock with similar digitations of the Serratus Anterior and Latissimus Dorsi. These three muscles, together with the Pectoralis Major and the Rectus Abdominis, whose attachments also interlock, cover the entire front and side of the thorax. The digitations of the External Oblique and Serratus interlock on the middle four ribs (5, 6, 7, and 8) and their pull produces slight bends, called the *anterior angles of the ribs*.

The External Oblique is fleshy above and laterally; elsewhere it is aponeurotic (*fig. 201*). The dividing line between the fleshy and aponeurotic portions curves from the anterior superior spine (or, more precisely, from an inch behind it) upwards and medially to the costal margin, which it meets at the lateral border of the Rectus Abdominis. The uppermost fibers of the External Oblique are nearly horizontal, and they end in an aponeurosis from which the Pectoralis Major in part arises. Its most posterior

fibers are fleshy and nearly vertical, and they fail to meet those of the Latissimus Dorsi at the midpoint of the outer lip of the iliac crest by one inch, more or less, thereby forming the *lumbar triangle.*

INSERTION. Between its upper horizontal and posterior vertical borders the fibers of the External Oblique spread out fanwise: (1) The fibers of the upper half of the muscle help to form the front of the Rectus sheath, decussate in the linea alba, and cross the middle line from xiphoid to symphysis. The lowest of these decussating fibers strike the front of the body of the pubis of the opposite side below the Rectus. They are referred to as the *reflected part of the inguinal ligament* (reflex inguinal lig.); occasionally they extend to the pectineal line. (2) The fibers of the lower half of the muscle find attachment between the lumbar triangle and the symphysis pubis as follows: (a) To the outer lip of the iliac crest from its midpoint to the anterior superior spine by fleshy fibers. (b) From the anterior superior spine to the pubic tubercle the muscle has a free, lower, aponeurotic border, known as the *inguinal ligament of Poupart.* The inguinal ligament bridges the muscles, vessels, and nerves passing from the abdomen to the front of the thigh; and it is convex towards the thigh due to the pull of the attached fascia lata. (c) Some fibers of the inguinal ligament pass beyond the pubic tubercle to the front of the body of the pubis; others, failing to reach the tubercle, are attached to the pectineal line of the pubis, as the *pectineal part of the inguinal ligament* (lacunar ligament). It will be seen when the muscle is reflected (p. 209). (d) Between tubercle and symphysis the aponeurosis is attached to the front of the pubis, below the Rectus. This part is largely ballooned out to cover the testis and is known as the *external spermatic fascia.* The mouth of the balloon is the *superficial inguinal ring.*

The Superficial Inguinal ring (subcutaneous inguinal ring) is an obliquely placed, triangular opening, one inch long. Its center lies above the pubic

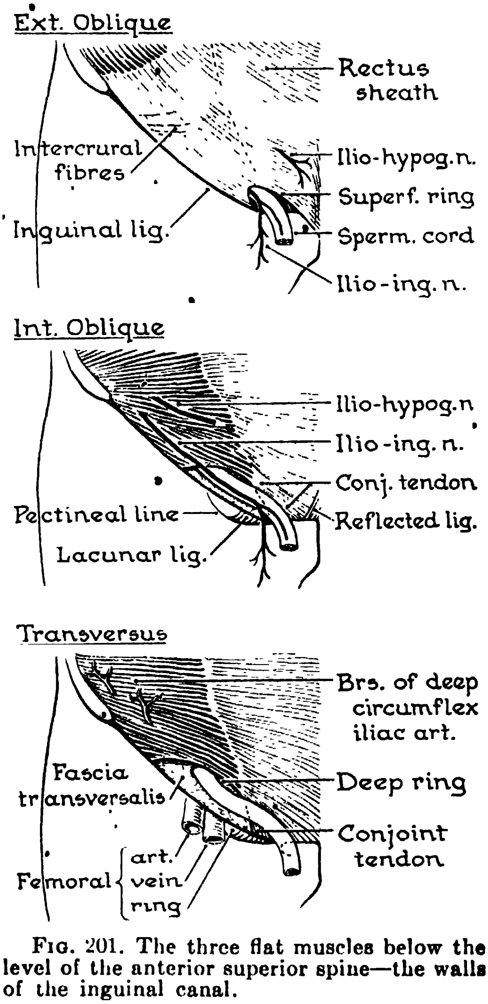


FIG. 201. The three flat muscles below the level of the anterior superior spine—the walls of the inguinal canal.

tubercle; its apex is lateral to the tubercle; its base, formed by the lateral half of the pubic crest, is medial to the tubercle. The two sides of the ring, known as the *upper and lower crura,* are thickened portions of the External Oblique aponeurosis.

The External Spermatic Fascia, derived

from the triangular portion of aponeurosis which at one time closed the ring, is, from the nature of its origin, attached to all three sides of the ring. It is thin and areolar in structure, not because it has been stretched to cover the testis, but because it is no longer subjected to the strains and stresses borne by the abdominal wall.

Some curved fibers, the *intercrural fibers*, lying lateral to the apex of the ring, tend to prevent its crura from spreading.

The Obliquus Internus Abdominis. The direction of the muscle fibers that form the floor of the lumbar triangle may be observed to pass antero-superiorly, at right angles to those of the External Oblique. Since these fibers belong to the Internal Oblique, it follows that the attachment of the Internal Oblique to the iliac crest must extent dorsally beyond the External Oblique for at least the width of the lumbar triangle, i.e., one inch behind the mid-point of the iliac crest.

Like the External Oblique, the Internal Oblique has a free, posterior oblique border except when its origin creeps upwards on to the underlying posterior aponeurosis of the Transversus (*fig. 286*).

The Internal Oblique, then, arises from more than the anterior half of the intermediate lip of the iliac crest, from more than the lateral half of the inguinal ligament, and commonly from the posterior aponeurosis of the Transversus.

INSERTION. (a) Its most posterior fibers ascend to the cartilages of the lower 4 ribs (12, 11, 10, and 9). The fibers that pass beyond the 9th cartilage necessarily miss the costal margin altogether and, continuing obliquely medially and upwards, split at the lateral border of the Rectus, contribute to the formation of the anterior and posterior walls of its sheath, and so reach the linea alba in which they decussate. The line of pull of these fibers prevents them from clothing the two or three inches of the Rectus just below the xiphisternal junction. (b) The fibers that proceed from the anterior superior spine pass horizontally; (c) those from the inguinal ligament curve downwards and medially to contribute to the conjoint tendon, described on the next page.

The Internal Oblique, does not extend above the costal margin. Consequently, it has a less extensive aponeurosis than the External Oblique which arises a hand's breadth above that margin.

The Transversus Abdominis has a pelvic, a lumbar, and a costal origin. The *pelvic origin* is fleshy from the inner lip of the iliac crest and from the inguinal ligament. Its attachment to the iliac crest is almost co-extensive with that of the Internal Oblique, but it extends to the lateral third only of the inguinal ligament. The *costal origin* is by fleshy slips that spring from the inner surface of the lower six costal cartilages where they interdigitate with fleshy slips of the Diaphragm. Between its iliac and costal origins it arises from the tips and borders of the transverse processes of the *lumbar vertebrae* through the medium of an aponeurosis called the middle layer of the lumbar fascia (*fig. 300, p. 296*).

From these three sites its fibers pass transversely forwards to decussate in the linea alba, those above the arcuate line passing behind the Rectus, those below passing in front. Its uppermost fibers have been seen to form a posterior fleshy relationship for the Rectus. The fibers arising from the lateral third of the inguinal ligament join the conjoint tendon. *The xiphoid process* may be re-

garded as an ossification extending from the body of the sternum into the aponeurosis of the Transversus.

The Conjoint Tendon (*Falx Inguinalis*). The inguinal parts of the Internal Oblique and Transversus join to form an aponeurosis which becomes part of the lower end of the Rectus sheath; and, though not fused with the External Oblique aponeurosis at this level, it is attached to the body of the pubis with it. This aponeurosis is prolonged laterally, behind the superficial inguinal ring, as a delicate sickle-shaped band which is attached to the medial half inch or more of the pectineal line (pecten pubis, p. 328). The aponeurosis and the band constitute the *conjoint tendon*. On pulling on the fleshy fibers of the Internal Oblique and Transversus, it becomes evident that both contribute to the aponeurosis, and that the Transversus alone ends in the sickle-shaped band. The band usually blends with the underlying fascia transversalis (Anson and McVay; and Chandler).

For the display of the attachment of the tendon to the pectineal line, the part must be moist and the point of the knife sharp. Press the inguinal lig. and its lateral or pectineal extension, also called the lacunar lig., firmly forwards, raise the spermatic cord and, using the handle and point of the knife, ease the conjoint tendon backwards from the lacunar lig. Both will be seen to be attached to the pectineal line, the lacunar lig. which represents External Oblique naturally being the more superficial.

The Cremaster Muscle is the covering the Internal Oblique and Transversus together give to the testis and spermatic cord. It is derived in the same manner as the external spermatic fascia (p. 207). It is, therefore, attached to the medial half of the inguinal ligament and to the pubis. It fills the concavity formed by the arching fibers of the two flat muscles, and in the scrotum its individual fleshy fibers form loops separated widely from each other by areolar tissue.

Its *nerve* is the genito-femoral (L. 1, 2).

Its *artery* is the cremasteric branch (ext. spermatic a.) of the inferior epigastric a.

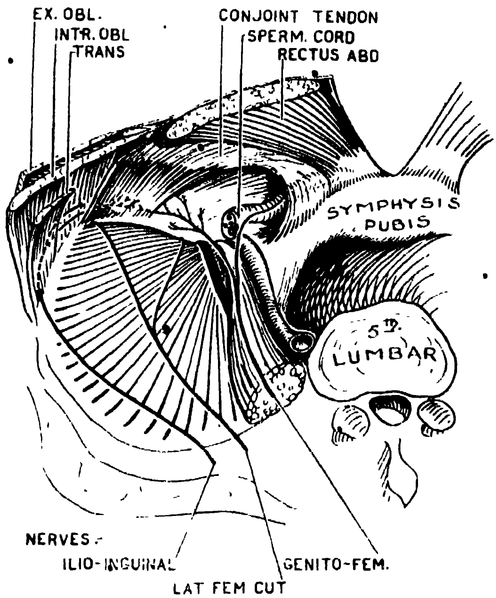


FIG. 202. Branches of the ilioinguinal and genitofemoral nerves to the muscle fibres controlling the conjoint tendon. (Dissection by Dr. R. G. MacKenzie.)

Its *action* is to retract or draw up the testis, and stroking the skin of the thigh supplied by the ilio-inguinal nerve (L. 1) reflexly brings about this retraction.

Functions of the 3 Flat Muscles. The Internal Oblique is thicker than the External Oblique, and each of these is much thicker than the Transversus which, in fact, is uniformly thin. The Oblique muscles are much thicker in the flanks than in front. They are the chief lateral

flexors of the trunk, and they give the Recti much help in forward flexion. The External Oblique fibers of one side and the Internal Oblique fibres of the other, being parallel, act together in rotation of the trunk. All three flat muscles help to maintain the intra-abdominal pressure, particularly the Transversus which is a living elastic corset. This pressure is much more important than ligaments and mesenteries in retaining the viscera in place.

The three flat muscles (a) by contracting alternately with the diaphragm as antagonist, help to bring about the expiratory act by their elastic recoil, and they are necessary to the abdominal form of respiration; (b) by contracting simultaneously with the diaphragm, they aid in expelling the contents of the abdominal organs (in micturition, defaecation, vomiting, and parturition) and in driving on venous blood to the heart. Their control of the inguinal canal is explained on page 212.

Above the Level of the Anterior Superior Spine the fibers of the three flat muscles run more or less at right angles to each other. A sufficient quantity of areolar tissue therefore is required between them to allow them to play across each other unimpeded.

Axiom. On cutting through the abdominal wall, the encountering of a layer of loose areolar tissue is a signal that a change in direction of muscle fiber is imminent.

The lower six thoracic nerves cling to the deep surface of the Internal Oblique. Their direction in the abdominal wall is apparently decided by the direction of their respective costal cartilages (*fig. 200*); i.e., the 7th and 8th nerves incline upwards; the 9th passes horizontally; the subsequent ones incline downwards; and all pierce the Rectus.

The ascending branch of the *deep circumflex iliac artery* pierces the Transversus in front of the anterior superior spine; the terminal branch pierces the Transversus just behind the spine. Both branches then ascend between Internal Oblique and Transversus. (*Fig. 201.*)

Axiom. When you incise the abdominal wall, the direction of muscle fibers, the presence of areolar tissue, the presence of nerves and of branches of the deep circumflex iliac artery all indicate the depth at which you have arrived.

Below the Level of the Anterior Superior Spine the anterior abdominal wall deserves careful attention on account of its great practical importance. In the male pubic hair extends upwards towards the umbilicus, and the suspensory ligament of the penis is attached to the lower part of the linea alba and upper part of the symphysis pubis.

Lateral to the Rectus the wall consists of eight layers, each of which is prolonged into the scrotum, and each must subsequently be accounted for there (*fig. 203*). In table 10 the names of the layers of the abdominal wall and the corresponding layers found in the scrotum are set out in parallel columns.

Let it be understood that the testis, like other abdominal organs (e.g., kidney and ureter; bladder and urachus; intestine, liver and spleen; the great vessels—but not the spinal nerves), develops in layer 7; that is to say, between the peritoneum and the fascia lining the muscles of the abdominal wall (e.g., Transversus, Ilio-Psoas, Diaphragm) (*fig. 204*). A month or so before birth the testis makes a descent through the abdominal wall. In descending it encounters the outer 6 layers of the wall and carries before it a tubular prolongation from each. Layers 1 and 2 form the *scrotum;* they do not envelope the testis and cord so snugly as

layers 3–6, which are known as the *coverings of the cord.* The testis drags after it its duct, arteries, veins, lymph vessels, and nerves, a quantity of the extraperitoneal tissue from layer 7 in which it is embedded, and a tube of peritoneum, called the *processus vaginalis,* belonging to layer 8. These constitute the *Spermatic Cord.* The passage through the abdominal wall is called the *Inguinal Canal.*

The foregoing is a simplified description. In reality, the testis is not the active agent in producing the tubular prolongations within which it is later contained. The scrotum and the coverings of the cord are formed early, even before the abdominal muscles differentiate, and, as Curl and Tromly properly point out, there is a definite inguinal canal in the male foetus before the testis passes through the abdominal wall, and in the female it is just as definite. Originally, the inguinal canal is an almost straight anteroposterior passage through the abdominal muscles; subsequently, during the process of growth, it becomes more oblique.

The Inguinal Canal. The first of the 8 layers of the abdominal wall that the testis encounters during its descent is, of course, the fascia lining the Transversus, known appropriately as the *fascia transversalis.* The tubular covering provided is the *internal spermatic fascia.* The mouth of this tube, called the *deep (abdominal) inguinal ring,* is the entrance to the inguinal canal. It lies a finger's breadth above the middle of the inguinal ligament and immediately lateral to the external iliac artery, (*fig. 201*):

The tube derived from the Ext. Oblique aponeurosis is called the *external spermatic fascia.* Its mouth, called the *superficial (subcutaneous) inguinal ring,* is the exit from the inguinal canal. It is triangular, 1″ long, easily admits the tip of a finger, and is so set that its apex is lateral and its base medial to the pubic tubercle.

Between the deep and the superficial inguinal ring the Transversus and Internal Oblique together contribute a tubular muscle covering, the *Cremaster*

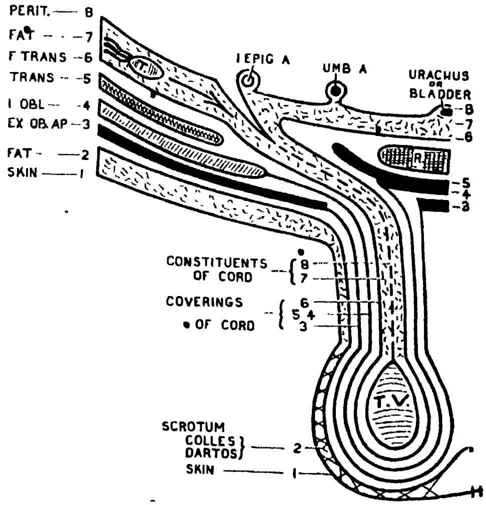


FIG. 203. Scheme: The inguinal canal, and the layers of the anterior abdominal wall prolonged into the scrotum. (See table 10.)

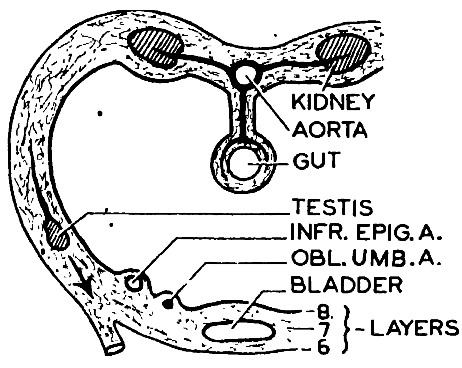


FIG. 204. The testis making its descent in layer number 7—i.e., the layer in which the organs and great vessels reside.

The Inguinal Canal extends from the deep inguinal ring to the superficial inguinal ring and is an inch and a half long. (a) The *anterior wall* is formed through-

out by the External Oblique aponeurosis, as figures 201 and 203 show. (b) The *posterior wall* is formed throughout by the fascia transversalis. (c) Between these two, the Internal Oblique and the Transversus are accounted for thus: Collectively, they lie in front of the most lateral part of the cord, arch over it, and lie behind its most medial part, i.e., they lie in front of the deep ring and behind the superficial ring. Considered individually, the Internal Oblique almost always arises from more than the lateral half of the inguinal lig., and therefore covers the deep ring and takes part in the anterior epigastric and the obliterated umbilical arteries. The inferior epigastric artery lies at the medial boundary of the deep ring and here the vas deferens takes a recurrent course lateral to it. (d) The *floor of the canal* is formed by the grooved surface of the inguinal ligament and by the pectineal part of the inguinal ligament (lacunar ligament).

What control has one over his canal: How is it closed? Your conception of the canal may be helped by likening it to an arcade of 3 arches formed by the Transverse and the two Oblique muscles (*fig. 205*). The contraction of the External

TABLE 10

THE LAYERS OF THE ABDOMINAL WALL	THE CORRESPONDING LAYERS IN THE SCROTUM	
1. Skin	1. Skin	Scrotum
2. Superficial fascia (a) fatty (Camper); (b) membranous (Scarpa)	2. Dartos muscle and fascia	Scrotum
3. External Oblique (aponeurotic)	3. External spermatic fascia	Coverings of the cord
4. Internal Oblique (fleshy)	4. Cremaster muscle	Coverings of the cord
5. Transversus (fleshy)	5. Cremaster muscle	Coverings of the cord
6. Fascia Transversalis (lining abdominal cavity in this region)	6. Internal spermatic fascia	Coverings of the cord
7. Extraperitoneal fatty tissue (layer inhabited by organs)	7. Areolar tissue with localized collections of fat	Two of the constituents of the cord
8. Peritoneum	8. Processus vaginalis	Two of the constituents of the cord

wall of the canal. But the origin of the Transversus is very variable; rarely does it extend to the deep ring and take part in the anterior wall; indeed in 26% of 110 regions its origin did not extend below the level of the anterior superior spine (Anson and McVay). As conjoint tendon (falx inguinalis) both muscles lie behind the superficial ring and therefore take part in the posterior wall, the Transversus making here the greater contribution. Behind the conjoint tendon lies the lateral part of the Rectus tendon which is an essential part of the posterior wall.

Running behind the posterior wall in the extraperitoneal fat are the inferior Oblique approximates the anterior wall to the posterior wall. The contraction of the arched fleshy fibers of (the inguinal portions of) the Internal Oblique and Transversus causes them to become straighter and taut. In consequence, the roof of the canal or arcade is lowered and the passage constricted. The action is that of a demi-sphincter.

The Eight Layers. Of the eight layers in this lower part of the abdominal wall, the *superficial fascia* consists of a superficial fatty layer of Camper, which is continuous with that covering the body generally, and a deeper membranous layer of Scarpa. In the scrotum the more superficial layer is devoid of fat, but it

contains involuntary muscle fibers, the *Dartos*, which are attached to the skin and cause it to wrinkle. It is not easily separated from the deeper membranous layer.

The External Oblique is here aponeurotic; and its aponeurosis must not be mistaken for deep fascia. Above the pubic tubercle the testis passed through this aponeurosis carrying before it a tube-like prolongation, the *external spermatic fascia.* This fascia is, of course, attached to the three margins of the triangular, superficial inguinal "ring". The infero-lateral margin (crus) of the ring is attached to the pubic tubercle. The supero-medial margin crosses the pubic crest at its middle to reach the front of the body of the pubis. The third side or base of the "ring" is the lateral half of the pubic crest.

The fleshy fibers of the *Internal Oblique* arise from more than the lateral half of the inguinal ligament and, therefore, cover the deep inguinal ring and help to form part of the anterior wall of the canal laterally The fleshy fibers of the *Transversus* arise from less than the lateral half of this ligament and, therefore, do not contribute to the anterior wall of the canal. The inguinal fibers of these two muscles, however, have a common origin, a common direction, and a common insertion, and, therefore, they behave as one muscle. There is, therefore, no occasion for areolar tissue between them, and as none exists, it is often difficult to separate them.

The areolar lining of the Transversus, known as the *fascia transversalis*, is relatively thick; so, it strengthens the inguinal region. In spare subjects the extraperitoneal layer of fat is reduced to an areolar framework. In the absence of fat the three innermost layers of the abdominal wall—namely the fascia transversalis, the areolar framework devoid of fat, and the peritoneum—blend to form a single areolar sheet; and you should not expect to be able to identify three (*fig. 206*). This is important. You may easily incise what you take to be fascia transversalis and find that you have opened the peritoneal cavity.

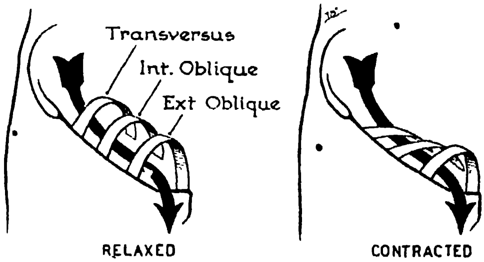


FIG. 205. "The inguinal arcade." The inguinal canal likened to an arcade of three arches traversed by the spermatic cord.

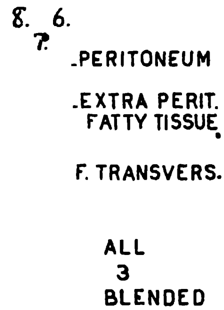


FIG. 206, In the absence of fat the inner three layers of the abdominal wall blend to form a single layer.

The *anterior rami* of the lower six thoracic nerves run between the Internal Oblique and the Transversus, but the ilio-hypogastric and ilio-inguinal branches of the anterior ramus of the first lumbar nerve run between the External Oblique and the Internal Oblique. To gain this more superficial plane, they pierce the Internal Oblique medial to the anterior superior spine. The ilio-inguinal branch then runs less than a finger's breadth above the inguinal ligament, and emerges

through the superficial ring lateral to the spermatic cord, but it may be anterior, or medial, or even posterior to it. The ilio-hypogastric branch runs at a higher level (*fig. 201*).

Just before piercing the Internal Oblique the *ilio-inguinal nerve* sends branches forwards to supply those fleshy fibres of the Transversus and Internal Oblique that control the conjoint tendon; the genito-femoral nerve also may send them a twig (*fig. 202*).

The Inferior Epigastric and Deep Circumflex Iliac Arteries arise from the external iliac artery just before it passes behind the inguinal ligament to become the femoral artery. The one ends within the Rectus sheath; the other between the Transversus and the Internal Oblique. To reach these destinations each must leave the extraperitoneal fatty layer in which it takes origin and pierce the fascia transversalis. *The inferior epigastric artery* does not require to pierce the posterior wall of the fibrous sheath of the Rectus, because for about three inches above the pubis this is wanting It is only necessary for it to pass in front of the arcuate (semicircular) line to find itself within the sheath. *The deep circumflex iliac artery* follows the inguinal ligament and, after piercing the fascia transversalis, gives off an ascending branch which pierces the Transversus an inch medial to the anterior superior spine; its terminal branches pierce the same muscle an inch lateral to the anterior superior spine.

THE TESTIS, SPERMATIC CORD, AND SCROTUM

The Descent of the Testis. The testis had its origin within the abdomen from the mesothelium or peritoneum covering the medial part of the mesonephros. In early fetal life a cord of spindle-shaped cells, called the *gubernaculum testis*, pushed before it into the scrotum the layers of the growing abdominal wall, and evaginated them as though they were so many sheets of rubber The upper end of the gubernaculum was attached (a) to the testis, (b) to the adjacent part of the peritoneum, and (c) to the mesonephric duct (later the epididymis and vas deverens) (*figs. 203, 207*). These it dragged after it, or at least it constrained them to follow in its wake. As a result, the peritoneum of the iliac fossa was elongated into a tube, the *processus vaginalis peritonei*, and the testis, which was adherent to the outer surface of the tube, was drawn with it into the scrotum. The lower end of the epididymis was drawn down too. (It is a common error to suppose that the testis drops into the tubular processus vaginalis like a bucket lowered by a rope into a well.) The lower end of the gubernaculum divided into a number of strands: the largest passed to the scrotum; others passed to the perineum, to the root of the penis, to the thigh and elsewhere. The testis descended to the iliac fossa during the 3rd fetal month; traversed the inguinal canal during the 7th fetal month; and reached the bottom of the scrotum after birth.

If the testis fails to leave the abdomen, the result is an *undescended testis;* if it follows the wrong strand of the gubernaculum the result is a misplaced or *ectopic testis* and an empty scrotum.

In the elephant the testis is retained in the abdomen; in certain rodents it descends periodically and then returns to the abdomen; in the pig it follows the strand of the gubernaculum to the perineum; in the marsupials it follows a prepenile strand.

The gubernaculum is, therefore, the helmsman of the testis. It is its forerunner.

To Display the Testis and Spermatic Cord an incision, extending from the superficial inguinal ring to a point half way down the scrotum, should be carried through skin, Dartos, and fascia. The external pudendal vessels, which cross in front of the cord on their way to supply the front of the scrotum, must be cut. The testis and cord in their three coverings are then to be shelled out of the scrotum; but it will be found that this cannot be done until a band of tissue that anchors the coverings over the lower pole of the testis to the scrotum is first snipped through. This band is perhaps a remnant of the gubernaculum. In it are some small veins.

The Scrotum is the bag of skin and subcutaneous tissues in which the testes lie. It consists of representatives of the outer two layers of the abdominal wall. The scrotum has a bilateral origin. It is derived from the right and left labio-scrotal folds. In the female these folds remain discrete as the labia majora; in the male they fuse behind the penis to form the scrotum. (*Fig. 208.*)

The skin of the scrotum forms a single pouch; the subcutaneous tissues of the scrotum form a right and a left pouch with a common median partition. The subcutaneous tissue is continuous with the fatty and membranous (Camper and Scarpa) layers of fascia on the abdomen, and with the fatty and membranous (Colles) layers of fascia in the perineum. It is, however, devoid of fat. It is laminated and it contains a sheet of involuntary muscle, the *dartos muscle.* The Dartos adheres to the skin and causes it to wrinkle when cold. Sympathetic fibers supply the Dartos.

Nerves. Branches of the 1st lumbar segment, via the ilio-inguinal nerve, supply the ventral part of the scrotum and the root of the penis; branches of the (2nd), 3rd, and 4th sacral segments, via the posterior scrotal nerves and perineal branch of the posterior femoral cutaneous nerve, supply the perineal part of the scrotum. Here, then, segments L. 2, 3, 4, 5, S. 1 (2) are not represented (*fig. 527*). There is, in fact, here a hiatus or break in the numerical sequence of the cutaneous nerves which corresponds to the segments from which the lower limb derives its nerves (*fig. 90*). This is comparable to the hiatus on the front of the

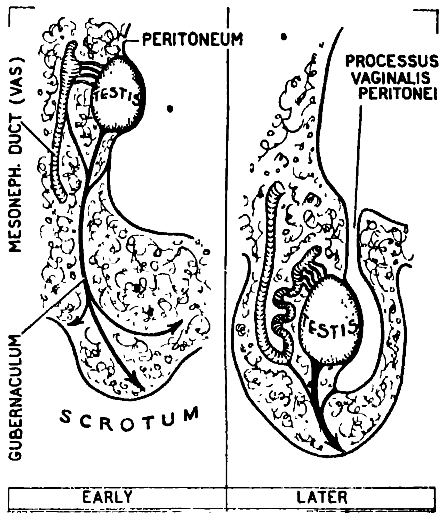


Fig. 207. Descent of the testis, processus vaginalis peritonei, and epididymis (side view—diagramatic).

chest where segments C. 3 and 4 meet segment Th. 2 owing to the withdrawal of segments C. 5, 6, 7, 8 and Th. 1 to form the brachial plexus.

Vessels. The *blood supply* of the scrotum comes from the external and internal pudendal arteries and veins. The *lymph vessels* return to the superficial inguinal glands.

The Three Coverings of the Testis and Spermatic Cord. These are continuous with the External Oblique aponeurosis at the subcutaneous inguinal ring, with the fascia transversalis at the deep inguinal

ring, and with the fleshy fibers of the Internal Oblique and Transversus between the two rings. The outer and inner coverings are known as the external and internal spermatic fasciae respectively, and between them is the middle covering or cremaster muscle. These tubular coverings tend to form a single areolar membrane in which the fibers of the Cremaster are spread out in wisps, but in a well preserved and muscular subject three layers can be dissected.

Supply. The Cremaster is supplied by segment L. 1 and 2, via the genitofemoral nerve, and by the cremasteric

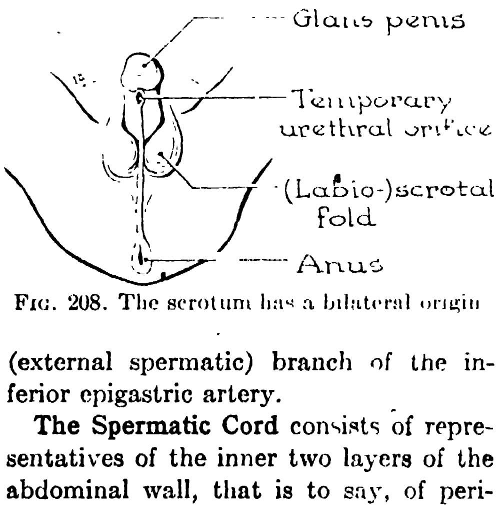


FIG. 208. The scrotum has a bilateral origin

(external spermatic) branch of the inferior epigastric artery.

The Spermatic Cord consists of representatives of the inner two layers of the abdominal wall, that is to say, of peritoneum and subperitoneal fatty-areolar tissue; and in the areolar-fatty tissue run the duct, vessels, and nerves of the testis, and the vessels and nerves of the epididymis. These constituents of the cord assemble at the deep inguinal ring lateral to the inferior epigastric artery, pass through the inguinal canal, and descend in the scrotum to the testis.

Observe (1) that the cord lies behind the Internal Oblique laterally, and in front of it medially where it forms the conjoint tendon, and here the cord rests on the pectineal part of the inguinal ligament (lacunar ligament); and (2) that, as the cord emerges from the superficial inguinal ring, it rolls over the pubic tubercle and covers it. So, in order to palpate the tubercle, it is necessary first to displace the cord either medially or laterally, which is easy to do.

The Constituents of the Cord are:

1. Representatives of the inner two layers of the abdominal wall:

(a) Processus vaginalis peritonei (funicular process and tunica vaginalis)

(b) Areolar tissue continuous with the subperitoneal fatty-areolar tissue.

2. Structures pertaining to the testis:

(a) The vas deferens.

(b) The vessels (artery, veins, and lymphatics) and nerves of the testis.

(c) The vessels and nerves of the vas deferens and epididymis.

The Processus Vaginalis Peritonei is the tube of peritoneum on which the testis is drawn by the gubernaculum into the scrotum. Its upper part lies in front of the vas deferens, and is obliterated before birth (or within a month after birth) and becomes a fibrous thread, the *funicular process of peritoneum.* While it remains patent, it conduces to inguinal hernia. Its lower part remains patent, is invaginated from behind by the testis, and is known as the *tunica vaginalis testis.* You will appreciate that though the testis migrates into the scrotum, it remains subperitoneal in the morphological sense.

Areolar Tissue, which is an extension of the subperitoneal fatty-areolar tissue, surrounds the processus vaginalis and forms a bed for the structures passing to and from the testis. In it are commonly found circumscribed *areas of fat,* which may attain the size of a pigeon's egg.

The Vas Deferens (ductus deferens) is the duct that conveys spermatozoa from the testis to the urethra. It is the continuation of the canal of the epididymis.

In length it equals the femur or the spinal cord. Morphologically, it is subperitoneal throughout its course (p. 342). Except at its two extremities, which are dilated and thin walled, it has a thick muscular coat and a capillary lumen; hence, it feels firm like a whip cord. It first ascends behind the testis along the medial border of the epididymis; it continues through the scrotum and inguinal canal as the posterior constituent of the spermatic cord; it then hooks round the lateral side of the inferior epigastric artery and descends subperitoneally to the postero-lateral angle of the bladder and thence to the urethra (p. 321).

Vessels and Nerves. There are two arteries in the spermatic cord —(1) the *testicular a.* and (2) the *deferent a.* The former and larger supplies the testis; the latter clings to the vas deferens and supplies it and the epididymis. The two arteries anastomose behind the testis;

The Veins of the Testis and Epididymis, a dozen or so in number, form an anastomosing plexus which, from its resemblance to a vine, is called the *pampiniform plexus.* The veins ascend in three longitudinal groups: the anterior group surrounds the testicular artery; the middle group surrounds the vas and its artery; the posterior group is alone. At the deep inguinal ring the veins are reduced to two or three, and subsequently to one. These veins not uncommonly become varicose (i.e., dilated and tortuous), a condition called varicocele (*p. 291*).

Lymph Vessels and Sympathetic Nerves accompany the arteries (*p. 219*).

The Testis (*fig. 209*). THE TESTIS is an ovoid gland measuring $1\frac{1}{2}$ x 1 x $\frac{3}{4}$ inches. It is enveloped in the *tunica vaginalis testis* except where the epididymis and the structures of the spermatic cord are attached to its upper pole and posterior border. It has a tough, fibrous, white, outer coat, the *tunica albuginea*, which is comparable to the sclerotic, white, outer coat of the eyeball. Posteriorly the outer coat is thicker and less dense and is known as the *mediastinum testis*. From the mediastinum fine areolar septa extend to the tunica albuginea and divide the testis into about 250 elongated pyramidal compartments or lobules. In each compartment two or more thread-like *seminiferous tubules* are

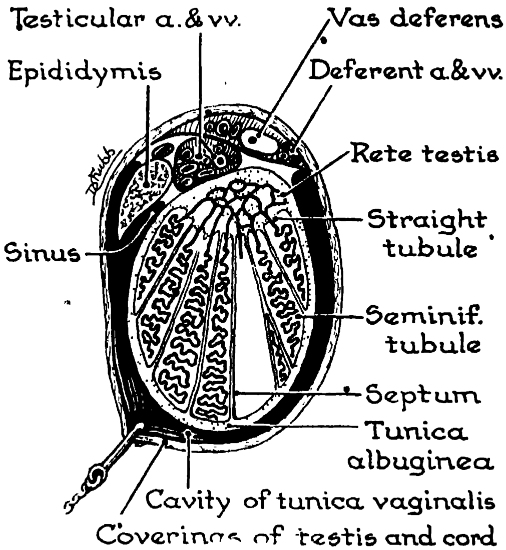


FIG. 209. Right testis in transverse section.

lodged. Being two feet long they are closely packed and convoluted, except at the apex of the compartment where they join together and take a short, straight course, the *straight seminiferous tubules.* In the mediastinum the straight tubules anastomose to form a network, the *rete testis.*

From six to a dozen fine ducts, the *efferent ductules*, connect the upper part of the rete testis with the head of the epididymis (*fig. 210*).

The Epididymis is applied to the upper pole and posterior border of the testis.

It is somewhat larger in diameter than a lead pencil. It tapers from above downwards. It is subdivided into a *head* or upper part, a *body* or intermediate part, and a *tail* or lower part. It has an attached, slightly concave, testicular surface, and a free rounded posterior surface which is largely covered with tunica vaginalis testis, that is to say, with peritoneum. A pouch of peritoneum, the *sinus of the epididymis*, dips in between the lateral side of the testis and the body of the epididymis. It indicates the side to which the testis belongs, being on the right side of the right testis, and on

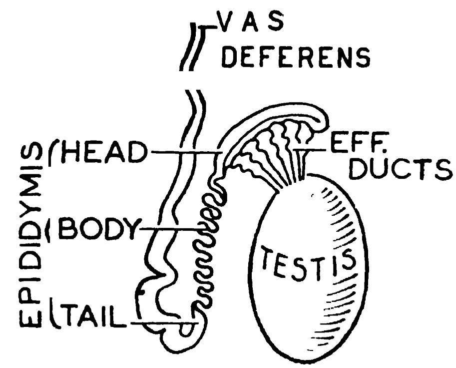


FIG. 210 The testis and epididymis.

the left side of the left testis. The vas deferens ascends on the medial side of the epididymis.

Structure. Each of the six to twelve efferent ductules of the testis coils to form a cone-shaped lobule. The lobules together comprise the head of the epididymis. They open into the duct of the epididymis. The duct of the epididymis forms the body and tail of the organ. It is greatly twisted and folded upon itself, and when unravelled it is as long as the small intestine, that is twenty feet or so. The tail ends in the *vas* or *ductus deferens.* The vas deferens is thin-walled and twisted where it ascends on the medial side of the epididymis, and it only acquires its characteristically thick muscle wall and a pin-point lumen near the upper end of the testis.

The head of the epididymis is in structural continuity with the testis through the efferent ductules, but the body and tail and the vas deferens are merely attached to the back of the testis by loose

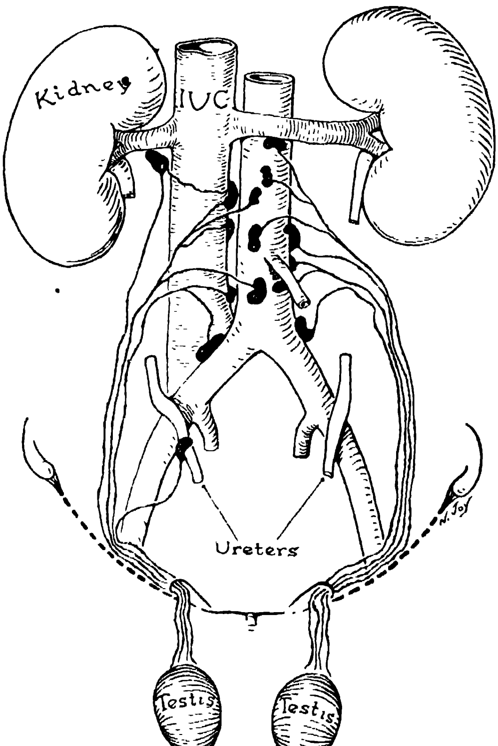


FIG. 211. The lymph drainage of the testes

areolar tissue and by the reflexion of the "peritoneum" on each side; so, they are easily dissected from it.

Vessels and Nerves. The testicular vessels (artery, veins, and lymphatics) and nerves bore through the posterior border of the testis and ramify on the inner surface of the tunica albuginea and on the septa. The deferent artery clings to the vas deferens, supplies it and the epididymis, and anstomoses freely with

the testicular artery behind the testis. It also anastomoses with the cremasteric artery. Tying the testicular artery, therefore, does not necessarily result in atrophy of the testis.

The vessels and nerves of the testis, like those of the ovary, extend to the kidney region where the sex glands developed.

with the lymph vessels of the scrotum and penis into the inguinal glands.

The nerve supply of the testis is derived from Th. 10, the segment that also supplies the region about the umbilicus. The epididymis is supplied by nerve segments Th. 11, 12, and L. 1 via the hypogastric plexus; so, the testis and epididymis are together supplied by the

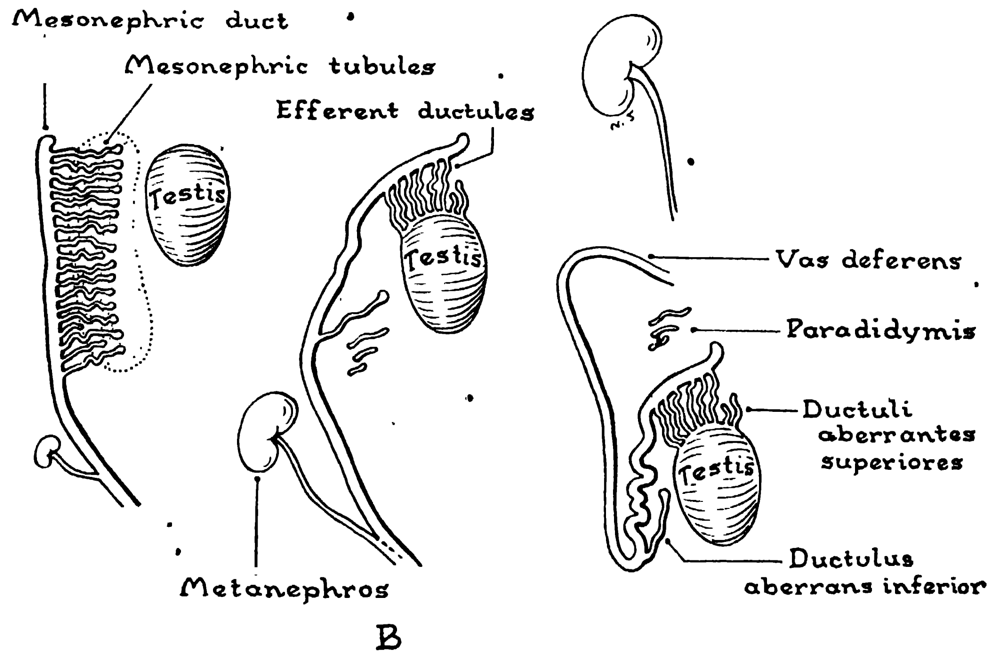


FIG. 212. Some mesonephric tubules become the efferent ductules; others persist as rudimentary or vestigial structures.

The testicular artery is a branch of the abdominal aorta; the pampiniform plexus of veins becomes a single vessel, the *testicular vein,* near the deep inguinal ring and ascends to end in the inferior vena cava on the right side of the body and in the left renal vein on the left.

The lymph vessels of the testis, also like those of the ovary, end in glands situated between the common iliac vein and the renal vein (*fig. 211*). It is a common error to suppose that they drain

same segments as the kidney, namely Th. 10, 11, 12, and L. 1.

The deferent artery is derived from the superior or inferior vesical artery; the *deferent vein* returns to the vesical plexus.

Development (*fig. 212*). *The duct system of the testis* is of three-fold origin: (a) The seminiferous and straight tubules and the rete testis are developed from anastomosing cords of cells in the genital ridge between vertebral segments L 4-S 2. (b) The efferent ductules and the

lobules in the head of the epididymis are formed from the six or more mesonephric tubules that succeed in establishing connections between the rete testis and the duct of the epididymis. (c) The duct of the epididymis and the vas deferens are derived from the Wolffian or mesonephric duct, that is to say, from the duct of the primitive kidney.

The Rudimentary Structures about the testis and epididymis are 5 in number. Of these, 2 are brought into view when the tunica vaginalis is opened. They are little bodies attached to the upper pole of the testis and head of the epididymis. They probably represent the cranial ends of the Mullerian and Wolffian ducts and are known as the *appendix of the testis* and the *appendix of the epididymis* respectively. The 3 other rudiments are revealed only when the epididymis is unravelled. They are the remains of mesonephric tubules. The ductulus aberrans superior is a tubule that has joined the rete testis but not the duct of the epididymis; the ductulus aberrans inferior is a tubule that has joined the duct of the epididymis but not the rete testis; and the *paradidymis*, is a collection of tubules that has joined neither. It forms a little body in the spermatic cord above the testis. These embryological remains may become cystic.

When the testis descends a fragment of spleen is rarely, a fragment of adrenal gland is occasionally, carried down with it.

CHAPTER 9

THE ABDOMINO-PELVIC CAVITY

Subdivisions. Before your studies of the abdomen have proceeded far, you will find it necessary to relate the various viscera and other structures to each other and to the surface of the body. This you can do readily and most satisfactorily if you employ the vertebral column of the individual in question as a scale and refer structures to their vertebral levels. Instead of thinking in inches and centimeters *think in terms of vertebral heights.* Obviously you will make use of the median sagittal plane to divide the body into right and left halves. Two horizontal planes, called the transpyloric and transumbilical planes, are guides to the vertebral levels. *The transpyloric plane* bisects the line joining the top of the sternum to the top of the symphysis pubis, and lies at the level of the disc between the first and second lumbar vertebrae. *The transumbilical plane* passes through the umbilicus and lies at the level of the disc between the third and fourth lumbar vertebrae. It is true that the level of the umbilicus varies somewhat with age, sex, obesity, and posture, but it is, for all that, a valuable landmark (*fig. 213*).

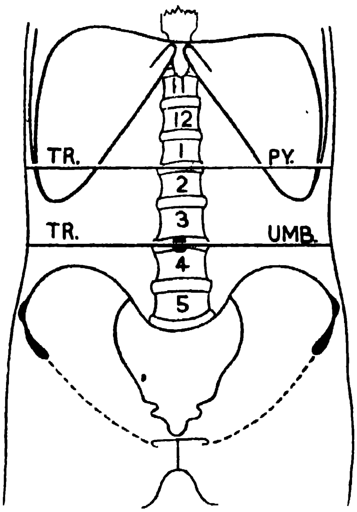


FIG. 213. Horizontal planes using the vertebral column as a measuring rod.

To remember the *vertebral levels* of these two planes—between 1 and 2, and between 3 and 4—should not tax the memory unduly.

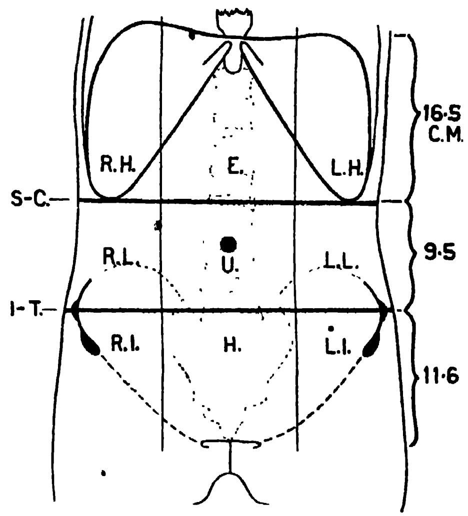


FIG. 214. The nine regions of the abdomen. RH, LH = right and left hypochondriac. RL, LL = right and left lumbar. RI, LI = right and left iliac. E = epigastric. U = umbilical. H = hypogastric.

For purposes of elaborate topographical work it is customary to divide the abdomen proper into three sections (upper, middle, and lower) by means of two horizontal planes; and to subdivide each section into three by means of two sagittal planes; making nine regions in all (*fig. 214*). The upper horizontal plane lies at the level of the lowest points of the chest wall seen from the front. These

points are on the 10th costal cartilages, and not on the 12th or 11th which are too short to reach the front. The lower horizontal plane lies at the level of the highest points on the iliac crests seen from the front. These are at the sites of the tubercles. The right and left sagittal planes are erected vertically on the midpoint of the line joining the corresponding anterior superior spine of the ilium to the top of the symphysis pubis This point is known as the *midinguinal point*. The names of these planes are: subcostal, intertubercular, and right and left "vertical Poupart".

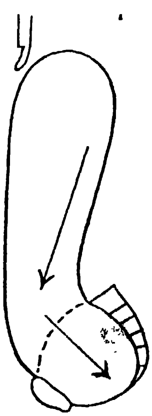


FIG. 215. The abdomino-pelvic cavity.

The upper and lower sections of the abdomen receive bony support behind and laterally, but the middle or umbilical section does not; consequently, it diminishes when you sit down and disappears entirely when you bend forwards. The subdivisions of the abdomen should, therefore, be plotted out with the subject either fully recumbent or else erect. The upper section rises to the diaphragm and is subdivided into epigastric and right and left hypochondriac regions; the middle section is subdivided into umbilical and right and left lumbar regions; and the lower section is subdivided into hypogastric (suprapubic) and right and left iliac regions.

We shall have but little occasion to refer to these regions except in a general way, as we find it more convenient and for the most part sufficient to work with vertebral levels.

A Blank Form. In making an outline sketch of the anterior abdominal wall of an average adult male, which it is profitable to do, the following data can be employed.

Length (xiphisternal junction to top of symphysis pubis)—37.6 cm.

Greatest breadth at subcostal plane—21.4 cm.

Greatest breadth at intertubercular plane (i.e., between tubercles on iliac crest)—27.4 cm.

Subcostal angle—58-90 degrees.

Depth of segments: subcostal—16.5 cm.; umbilical—9.5 cm.; hypogastric—11.6 cm.

Interspinous diameter (between anterior superior iliac spines)—23.3 cm.

Diameter between pubic tubercles—5.3 cm.

Length of sternum (manubrium and body)—16.7 cm.

Length of symphysis pubis (true length)—4.7 cm.

The pelvic brim divides the abdomino-pelvic cavity into the ***abdominal cavity proper*** and the ***true pelvis*** These two subdivisions are set nearly at right angles to one another, and it would seem that the weight of the abdominal viscera is borne largely by the portion of the anterior abdominal wall lying below the level of the anterior superior iliac spines and by the posterior surface of the bodies and superior rami of the pubes (*fig. 215*).

Protection to Viscera. The abdominal viscera lie largely within the thorax and pelvis. This statement requires qualification. Of course the viscera are not within the thoracic cavity, for they are situated below the diaphragm; but, since the diaphragm rises to the level of the fifth rib in the mammary line, the upper

viscera are certainly well ensconced within the bony thorax. The lower viscera lie within the false pelvis protected behind and at the sides by the ilia. In the flanks only the breadth of two fingers separates the eleventh ribs from the iliac crests. The ventral aspect of the abdomen, being within the field of vision, can be defended by the upper limbs and can be protected by bending forwards or by curling up; so, it is in less need of bony protection.

Definitions. *The Peritoneum* is an areolar membrane covered with a layer of squamous epithelial cells, the areolar membrane being to the cells what a wall is to the wall-paper covering it—necessary for its support. In the male the complicated bursa, called the *peritoneal cavity,* is lined everywhere with peritoneum. In the female (a) the ovaries are covered with cubical cells; (b) the fringes that project from the mouths of the uterine tubes are covered with ciliated columnar cells; and, (c) the peritoneal cavity communicates with the exterior through the uterine tubes, uterus, and vagina; so, the definition applicable to the male must in three respects be modified for the female. The portion of peritoneum lining the walls or parietes of the peritoneal cavity is called the *parietal layer* of peritoneum; that covering the organs or viscera is the *visceral layer.* The peritoneum forms folds or double layers. A fold of peritoneum connecting the stomach to another organ is called an *omentum;* of these there are three: (a) the gastro-hepatic or lesser omentum, (b) the gastro-colic or greater omentum, and (c) the gastro-splenic omentum (or ligament). A fold connecting the intestine to the posterior abdominal wall and conveying vessels and nerves to it is a *mesentery.* All other folds are called *ligaments.* The distinction, however, between the three terms is not one of importance.

Identification of the Abdominal Viscera. At this stage *let the following structures* (*fig. 216*) *be identified:* The *diaphragm,* which forms the roof of the abdomen; the *liver,* lying above and mainly on the right side, is divided into a right and a left lobe by the *falciform ligament* which connects the liver to the

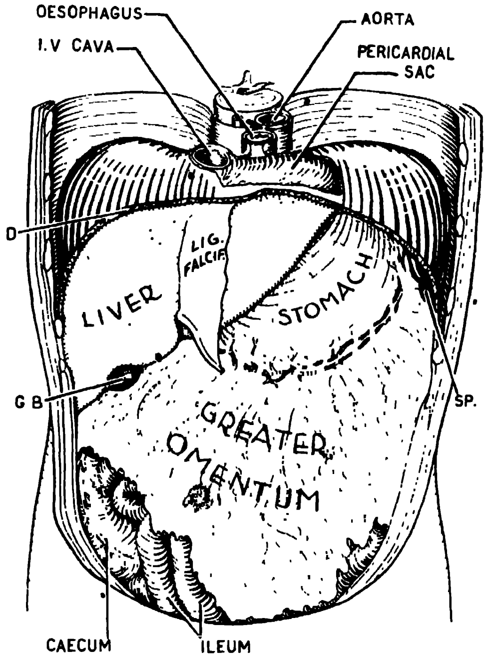


FIG. 216. Abdominal contents undisturbed. G.B. = gall bladder; Sp = spleen; D = cut edge of diaphragm.

diaphragm and anterior abdominal wall in the median plane; the *gall bladder,* lying on the under surface of the liver reaches to or beyond its sharp, inferior border at the lateral margin of the Rectus Abdominis; the *stomach,* above and to the left; the *spleen,* behind the stomach and in contact with the diaphragm. Then let the *greater omentum,* which hangs like an apron from the greater curvature of the stomach, be thrown up-

wards over the costal margin when the *small intestine*, surrounded by the *large intestine*, as though by a picture-frame, will be seen. The *greater omentum*, also called the gastro-colic omentum, may now be followed to the portion of the large gut called the *transverse colon*; the broad, conspicuous *transverse mesocolon*, passing from transverse colon backwards to the *pancreas*, is readily observed, although the pancreas cannot be identified at this stage. The rounded lower poles of the right and left *kidneys* can and should and

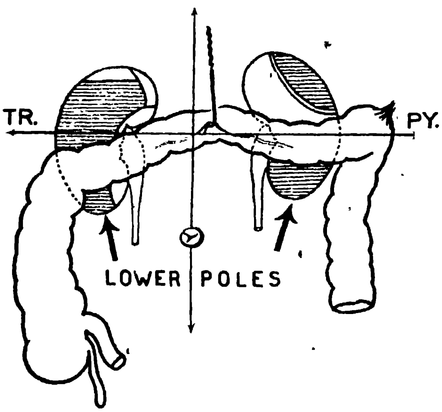


FIG. 217. The shaded parts of the kidneys are covered by the greater sac and therefore are palpable when the peritoneal cavity is open.

indeed must be palpated in the upper angles of the intestinal "picture frame" (*fig. 217*). It may, however, first be necessary to steady the kidney by placing the unoccupied hand behind the lumbar region and pressing forwards below the last rib. The lateral convex border of each kidney should be traced above the colic flexure and part of the anterior surface palpated. The empty *urinary bladder* lies behind the pubis; the *rectum* lies in front of the sacrum.

The Parts of the Gastro-intestinal Canal or Tract.

Before handling the structures any further, let the names and general dispositions of the various parts of the gastro-intestinal canal be learned by reference to figure 218. The alimentary or digestive canal is divisible into the following parts: the mouth, pharynx, oesophagus, stomach, small intestine, and large intestine. Only the upper and lower ends of the alimentary canal occupy the median plane of the body; these are: the mouth, pharynx, and upper portion of the oesophagus above; and the lower part of the rectum and the anal canal below. The stomach and intestines (i.e., from stomach to anus inclusive) are collectively called the gastro-intestinal canal. The last inch of the oesophagus and the gastro-intestinal canal are situated within the abdomen.

The *oesophagus* pierces the diaphragm less than an inch to the left of the middle line and ends at the oesophageal orifice of the stomach. The *stomach* lies to the left of the middle line. Its exit, the *pylorus*, lies less than an inch to the right of the middle line in the transpyloric plane. It is succeeded by the small gut, which is subdivided into 3 parts: intestinum duodenum, intestinum jejunum, and intestinum ileum. The *intestinum duodenum* is the horseshoe-shaped portion of the small gut that has lost its mesentery. It begins at the pylorus and ends at the *duodeno-jejunal junction*, an inch to the left of the middle line just below the transpyloric plane, i.e., about two inches from where it begins. Having no mesentery, the duodenum adheres to the structures on the posterior wall of the abdomen. On this account and because the transverse colon crosses it and adheres to it, it is not conspicuous. The *intestinum jejunum* and the *intestinum ileum* are the two parts of the small gut which retain their mesenteries. They extend from the duodeno-jejunal junction to the right iliac fossa where the ileum opens

into the large gut. The opening is called the *ileo-colic orifice*.

The *subdivisions of the large intestine* are: the vermiform appendix, the intestinum cecum, ascending colon, right colic (or hepatic) flexure, transverse colon, left colic (or splenic) flexure, descending colon, pelvic colon, intestinum rectum, anal canal, and anus.

splenic) flexure. From here the *descending colon* descends to the pelvic brim where it becomes the pelvic colon. (The segment traversing the left iliac fossa was formerly called the iliac colon.) As *pelvic colon* it passes to the middle of the sacrum where it becomes the *intestinum rectum*. The lower portion of the rectum and the anal canal pass through the floor

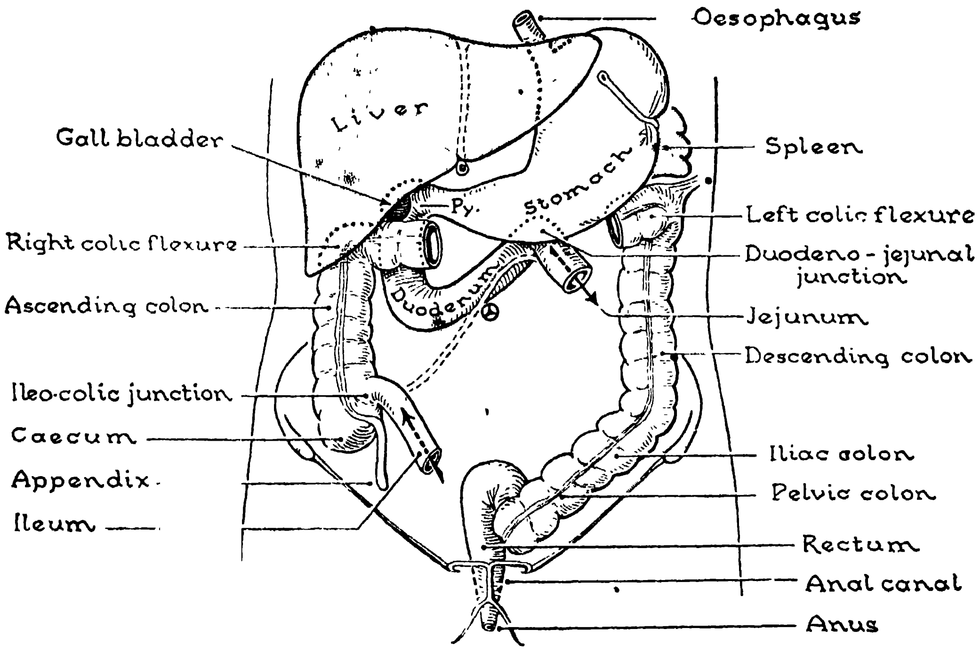


FIG. 218. The names of the various parts of the digestive tract and their dispositions.

The *cecum* is the blind cul-de-sac situated below the ileo-colic orifice. The worm-shaped *appendix* opens into the cecum less than an inch below the ileo-colic orifice. The *ascending colon* ascends from the right iliac fossa, across the iliac crest, to the under surface of the liver where, in front of the kidney, it makes a bend, the *right colic (or hepatic) flexure*, and becomes the *transverse colon*, which extends across the abdomen to the under surface of the spleen where, in front of the left kidney, it becomes the *left colic (or*

of the pelvis and in the perineum open on to the surface as the *anus*.

Examination of the Gastro-intestinal Canal. *By inspection and by handling proceed now to examine the abdominal portions of the alimentary canal.* The last inch of the *oesophagus* lies in a groove on the posterior aspect of the attenuated left lobe of the liver. The *stomach* has an entrance and an exit: the one, the oesophageal or cardiac orifice, is situated an inch to the left of the middle line behind the 7th costal cartilage; the other, the

pylorus, is situated an inch or less to the right of the middle line on the transpyloric plane The two borders of the stomach extend between these two orifices. The upper border or lesser curvature is short and concave and, with the first inch of the duodenum, gives attachment to the lesser or *gastro-hepatic omentum.* The lower border or greater curvature is long and convex and, with the first inch of the duodenum, gives attachment to a large peritoneal fold of which the left portion is the *gastro-splenic omentum,* and the lower portion is the *greater* or *gastro-colic omentum.*

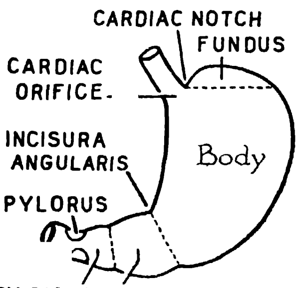


FIG. 219. The parts of the stomach.

The stomach is subdivided thus: a line drawn horizontally at the level of the oesophageal orifice separates the *fundus* from the *body.* An oblique line joining an indentation on the lesser curvature (incisura angularis) to the greater curvature separates the body from the pyloric end of the stomach. Another oblique line passing from an indentation on the greater curvature (sulcus intermedius) to the lesser curvature subdivides the pyloric end into a large chamber, the *pyloric antrum,* and a more tubular portion, the *pyloric canal.* By invaginating the anterior wall of the stomach with the index finger and the anterior wall of the duodenum with the thumb, the tips of these two digits can be made to meet in the lumen of the *pylorus* and the thickness of its sphincter gauged (*fig. 219*).

The *duodenum* is the fixed part of the small gut or the part that has lost its mesentery. Though ten inches in length its two ends are but two inches apart, for it begins at the pylorus, which lies on the transpyloric plane less than an inch to the right of the middle line, and ends at the duodeno-jejunal junction, where it is continuous with the jejunum, an inch to the left of the middle line and a little below the transpyloric plane. It is moulded around the head of the pancreas and is horseshoe-shaped. It is subdivided into a 1st or superior part, a 2nd or descending part, a 3rd or horizontal part, and a 4th or ascending part. The 2nd part is largely concealed by the transverse colon which crosses it and adheres to it.

The *remainder of the small gut* retains its mesentery and extends from the duodeno-jejunal junction to the ileocolic orifice, which is situated in the right iliac fossa where intertubercular and vertical Poupart planes intersect. Though a space of but 6 inches divides the two points, the gut, under dissecting room conditions, steers a varying course of 20 odd feet between them. The root of the mesentery of the gut is attached diagonally across the posterior abdominal wall between the two points and is, therefore, also six inches long, while its intestinal border is elaborately ruffled and frilled to accommodate the gut. The small intestine is so convoluted and mobile that you can pass many feet of it through your hands without being able to decide whether it is leading you to its duodenal end or to its cecal end. But, by the simple device of placing a hand on each side of the mesentery and drawing the fingers forwards from root to intestinal border, the

convolutions are locally untwisted and the direction of the gut rendered quite obvious.

The *first coil of the jejunum* and the *last coil of the ileum* are parallel to each other; the former passes downwards and to the left in front of the left kidney, the latter passes upwards and to the right out of the pelvic cavity (*fig. 218*).

The *jejunum contrasted with the ileum.* The upper two-fifths of the free part of the small gut are called jejunum, the lower three-fifths ileum. The jejunum has a greater digestive surface than the ileum, on account of the facts that its *diameter* is greater; its spirally arranged folds of mucous membrane, called *plicae circulares*, are bigger and more closely packed; and its minute finger-like projections, called *villi*, are larger and more numerous. Its walls therefore feel thick and velvety. The wall of the smaller calibred ileum with its fewer plicae and villi may be almost parchment-like in thinness. Follicles of *lymphoid tissue* are scattered throughout the small and the large gut, and in youth *aggregated lymph nodules* (Peyer's patches), from one to two inches long and half-an-inch wide, are visible in transmitted light throughout the ileum and in the lowest part of the jejunum. They are situated only at the anti-mesenteric border. The *fat*, normally present in the mesentery, creeps along the vessels on to the ileal wall but fails to reach the jejunal wall; hence, there are translucent "windows" in the mesentery at the edge of the jejunum. Further, on holding the gut and mesentery to the light, the disposition of the *vessels* is seen to become progressively more complex from the beginning of the jejunum to the end of the ileum; thus, the *vasa recta* or straight terminal vessels to the upper quarter of this section of the gut spring from a single system of arcades; to the 2nd quarter from a double system of arcades; to the 3rd quarter from a treble system; and to the last quarter from a system of four arcades. At the same time the vasa recta become progressively shorter. The vasa recta pass more or less alternately to opposite sides of the gut, where they arborize. Now, the vasa recta are end-arteries; i.e., they themselves do not anastomose al-

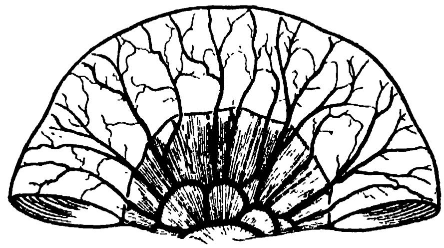


FIG. 220. The arteries of the jejunum (from an injected specimen).

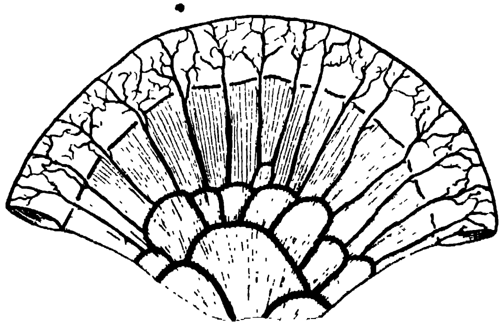


FIG. 221. The arteries of the ileum (from an injected specimen).

though their capillary arborizations in the gut wall do so. If, therefore, one vas rectum is obstructed, the maintenance of the circulation within its territory is precariously dependent on capillary anastomoses (*figs. 220, 221*).

The *large gut* forms 3½ sides of a square around the small gut; so, by their relative positions the one may be told from the other. The outer longitudinal muscle coat of the large gut does not form a complete coat, as in the small gut, but it is

arranged in three narrow bands, the *teniae coli*, which, being shorter than the gut itself, cause it to be gathered up into *sacculations*. As evidence of this, observe that if the teniae are cut the sacculated form is lost. Peritoneal bags of fat, *appendices epiploicae*, hang from the large gut throughout its whole length (*fig. 222*). Those from the appendix, cecum, and rectum generally contain no fat, and resemble the appendix of the testis; they may be absent. Most ap-

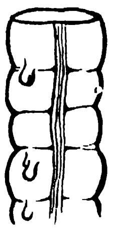


FIG. 222. Segment of large intestine showing one of the three taeniae, sacculations, and appendices.

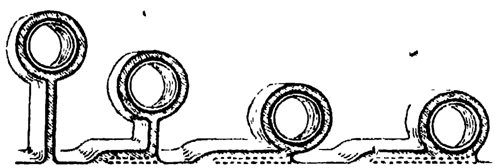


FIG. 223. Primitive mesentery of the large gut in various stages of absorption.

pendices are attached to the colon between its "inner margin" and the anterior tenia, but in the iliac and pelvic colons they are in two rows, one on each side of the anterior tenia. Size alone does not necessarily distinguish large gut from small gut, the descending colon having commonly a *calibre* less than that of the small gut. *The primitive mesentery*, possessed by the large gut in foetal life, is constantly retained by the transverse and pelvic colons, while the appendix acquires a mesentery, and the cecum is free. The extent to which the ascending and descending colons lose their primitive mesenteries varies (*fig. 223*): the mesentery may persist (a) wholly, or (b) in part; but usually the loss is complete the colon being either (c) surrounded with peritoneum on all sides, or (d) surrounded on three sides and bare posteriorly.

The *cecum* is free and commonly lies in the right iliac fossa below the intertubercular plane and lateral to the vertical Poupart plane. Its rounded lower end (or fundus or caput) often hangs over the pelvic brim. The cecum may have

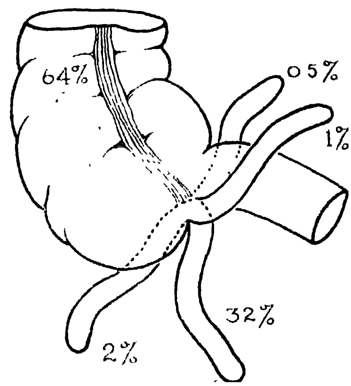


FIG. 224. The various sites assumed by the vermiform appendix and their approximate frequencies. (After Wakeley.)

a short mesentery or even two mesenteries, a medial and a lateral, with a cul-de-sac, the *retrocecal fossa*, extending upwards between them. When present, this fossa usually contains the appendix. An extensive retrocecal fossa (i.e., one extending upwards behind the ascending colon) is, of course, a *retrocolic fossa.*

The *vermiform appendix* (vermiform process) in fetal life opened into the apex of the cecum, now it opens into the cecum an inch or less below the ileo-colic junction. Like the hands of a clock, the appendix may be long or short, and may occupy any position consistent with its

length. In 10,000 cases Wakeley found it to be either postcecal or retro-colic in 65.28 per cent; pelvic (on the Psoas, near or hanging over the pelvic brim) in 31.01 per cent; and rarely elsewhere; i.e., subcecal, preileal, postileal, or ectopic, e.g., in a hernial sac (*fig. 224*).

A triangular fold of peritoneum, known as the *meso-appendix*, attaches the appendix to the terminal part of the left (lower) layer of the mesentery of the ilium; but retrocecal and retrocolic appendices commonly lose their mesenteries and

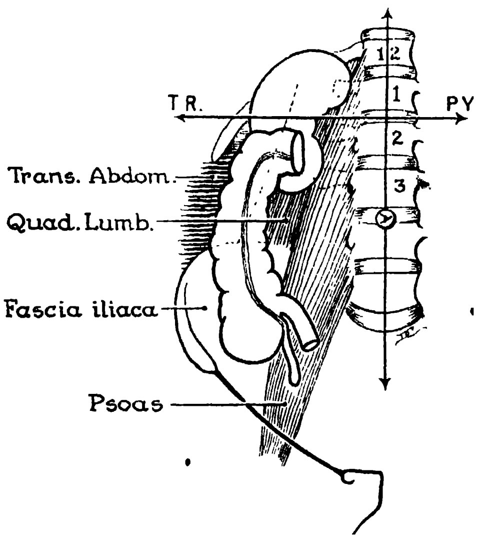


FIG. 225. The ascending colon.

adhere to the posterior abdominal wall or to the cecum. The appendix has a uniform external coat of longitudinal muscle fibers. At its base these fibers separate into the three teniae coli which remain discrete till they reach the rectum when they form for it a nearly uniform coat again. The *ascending colon*, like the cecum and appendix, rests on the strong fascia iliaca in the false pelvis; it then crosses the iliac crest and ascends in front of the Quadratus Lumborum and Transversus Abdominis to the under surface of the liver where, in front of the lower pole of the right kidney, it makes a right-angle bend, the *right colic* (*hepatic*) *flexure*, and becomes the *transverse colon* (*figs. 225, 301*). Resting on the transverse colon are: the right lobe of liver, the body of the gall bladder, the quadrate lobe of the liver, and the greater curvature of the stomach. The lower border of the transverse colon is attached to the lower border (greater curvature) of the stomach by the *greater omentum*. The upper border is slung from the anterior aspect of the body of the pancreas by a semilunar, double layer of peritoneum, called the *transverse mesocolon*. The right extremity, however, crosses and adheres to the anterior aspects of: the right

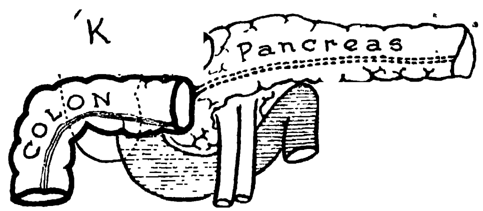


FIG. 226. The attachment of the transverse mesocolon (shown by dotted lines).

kidney, the second part of the duodenum, and head of the pancreas (*fig. 226*). Thus, the right extremity is fixed; the remainder is free and hangs down for a varying distance but ascends again in front of the descending colon, and makes with it an acute angle at the left colic flexure. The *left colic* (*splenic*) *flexure* is attached to the diaphragm below the spleen, and therefore at the level of the 11th rib (*fig. 230*), by a bloodless fold of peritoneum, the *phrenico-colic ligament*. The *descending colon*, often much reduced in calibre, descends, crosses the iliac crest, and proceeds across the iliac fossa to the pelvic brim where it becomes the pelvic colon. (This iliac portion of the colon may be called the *iliac colon*.)

The *pelvic colon* has a mesentery, the *pelvic mesocolon,* whose root runs a Λ-shaped course: (a) upwards along the pelvic brim (*actually*, along the medial border of the Psoas) and then (b) downwards in front of the sacrum as far as its middle or third piece. Its appendices epiploicae are very long fatty tags. The pelvic colon may be of the short or long type—8 inches to 18 inches. The long type crosses to the right of the pelvis and returns before taking the restricted course of the short type. The long type may be regarded as the short type to which a loop has been added. The long loop type is apt to rotate and become twisted on itself, thereby causing intestinal obstruction. Where the mesentery of the pelvic colon ceases, there the

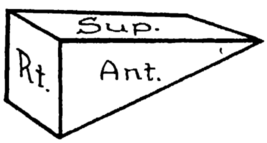


FIG. 227. The general shape of the liver.

rectum is said to begin; usually this is at the 3rd piece of the sacrum. The rectum lies in the pelvis and it will be studied with the pelvic organs.

The Viscera in the Upper Regions of the Abdomen and Their Peritoneal Connections Are Now to be Examined and Handled. In order that this may be done, the greater omentum, which was thrown up, must now be thrown down again. You should satisfy yourself thoroughly on each point mentioned, either on the body you are studying or on another. Perform no dissection until page 247 is reached.

The Liver (hepar, L.) is a soft, pliable organ, which is moulded by its surrounding structures. It owes to them its ever changing form. The hardened liver is shaped like an oblong block bisected diagonally and with its inferior surface whetted away posteriorly (*fig. 227*). Its anterior, superior, and right lateral aspects are covered with peritoneum, and are applied to the diaphragm and anterior abdominal wall, and by them are rounded into one extensive, smooth, *convex surface.* The *posterior surface* also is in contact with the diaphragm, but it cannot be seen just now (*fig. 233*). The remaining surface is the *inferior or visceral surface.* It is separated from the large, convex surface by the *sharp, in-*

FIG. 228. The four relations of the gall bladder (sagittal section).

ferior border, and it bears the impress of every structure in contact with it.

The Gall Bladder is divided indefinitely into—*fundus*, *body*, and *neck*. The fundus of the gall bladder projects beyond the sharp, inferior border of the liver and comes into contact with the anterior abdominal wall where the lateral border of the Rectus crosses the costal margin (*fig. 197*). The body and neck run dorsally on the inferior surface of the liver, to which they adhere, to the right end of the porta hepatis. The *porta hepatis* is the main door through which the vessels, nerves, and ducts enter

and leave the liver. It is a transverse fissure in the liver substance to which the right half of the lesser omentum is attached. You have seen that the transverse colon crosses the second part of the duodenum. Restore structures to their places and note that the gall bladder rests on the duodenum and on the colon; and that a gall-stone could penetrate its way through the walls of the gall bladder into: (1) the liver substance, or after traversing the peritoneal cavity, (2) into the duodenum, (3) into the colon, or (4) through the anterior abdominal wall. For these four structures are the immediate relations of the gall bladder (*fig. 228*).

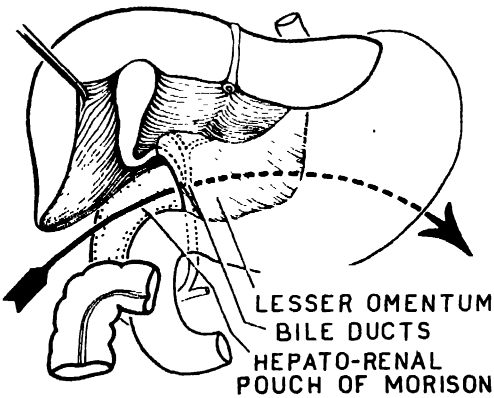


FIG. 229. Showing why the gall bladder serves as a guide to the mouth of the lesser sac of peritoneum.

A gall bladder is present in most species of fish and in orders of vertebrates higher than fish. It is curious that it should be present in most species of birds but absent in the pigeon; present in the ox, sheep, goat, and pig, but absent in the horse and deer; present in the guinea pig and rabbit, but absent in the white rat; and generally absent in the cetaceae.

The Mouth of the Lesser Sac (Epiploic Foramen). The term "lesser sac" presupposes a "greater sac". The general peritoneal cavity is to be thought of as the greater sac. The gall bladder serves as a guide to the mouth of a peritoneal diverticulum, called the *lesser sac of peritoneum*. This is because the *cystic duct*, which drains the gall bladder, lies in the free edge of the lesser omentum; and the mouth of the sac lies behind this free edge. If, then, the left index finger follows along the fundus, body, and neck of the gall bladder, it will arrive at the cystic duct and the free edge of the lesser omentum; and, on slipping behind this free edge, it will enter the mouth of the lesser sac. In shape, the lesser sac is not unlike an empty, rubber hot-

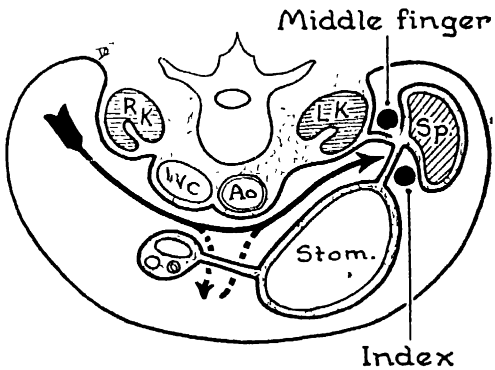


FIG. 230. Palpating the hilum of the spleen while its pedicle is clamped between two fingers of the right hand.

water-bottle, placed horizontally with its narrow mouth opening to the right. (*Figs. 229, 230.*) See also p. 247.

The Peritoneal Attachments of the Spleen (Lien, L. = Spleen). To find the spleen you should stand on the right side of the body, as so doing will allow you to thrust your right hand above the phrenico-colic ligament into the left hypochondrium and with the backs of your fingers to follow with comfort the diaphragm round to the back. The spleen will then lie within your palm. You have, so to speak, scooped it into your hand. It is situated further back than you perhaps thought. Adhesions

that can be broken down with the fingers sometimes cause the spleen to adhere loosely to the diaphragm. After consulting figure 230, verify that in the foregoing maneuver your fingertips passed from the diaphragm across the anterior surface of the *left kidney* until arrested by the *lieno-renal ligament*, which, as its name implies, passes from spleen to kidney. A second duplicature of peritoneum, continuous with the greater omentum, passes from the greater curvature of the stomach to the spleen; this

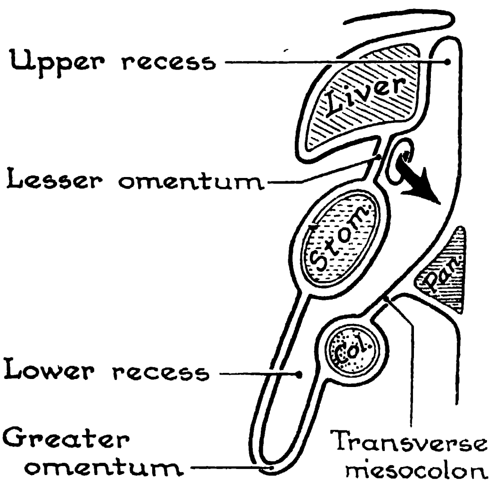


FIG. 231. Showing the vertical extent of the lesser sac. The arrow passes through the mouth of the lesser sac.

is the *gastro-splenic ligament* (or omentum). These two ligaments suspend the spleen between the kidney and the stomach, and form a stalk or pedicle for it. Vessels run between their layers.

The Pedicle of the Spleen: The Lesser Sac of Peritoneum (OMENTAL BURSA). While still standing on the right side of the body, run your right middle finger upwards between the kidney and the spleen, and your right index finger upwards between the stomach and the spleen. The "pedicle or stalk" of the spleen now lies in the cleft between these two fingers as though in a clamp. The pedicle has a free lower border (and a free upper border) or you could not grasp it as you are doing. Its linear site of attachment to the spleen is around the hilum. Clamped between your index and middle fingers are four layers of peritoneum. Of this you can satisfy yourself by passing your left index finger through the mouth of the lesser sac and across the abdomen, behind the stomach, till it touches the spleen between your two right fingers which are clamping the "pedicle". If your left index will not reach all the way, pass it as far as it will go, tear through the lesser omentum over its tip, withdraw the finger, and reinsert it at the half-way opening just made. The hilum of the spleen, which you are palpating, is situated at the left extremity of the lesser sac. To explore the lower limit of the sac, pass your left index through its mouth and downwards behind the stomach and anterior two layers of greater omentum and in front of the pancreas, transverse mesocolon, transverse colon, and posterior two layers of the greater omentum. If the lower limits of the sac are shut off from the main portion, they can be investigated after snipping through the anterior two layers of the greater omentum below the stomach. To explore the upper limit of the sac, pass the right index through its mouth and upwards in the median plane between the liver and the diaphragm (*fig. 231*).

The Peritoneal Attachments of the Liver. The *falciform ligament* of the liver is developmentally "the mesentery of the vein" which before birth returned purified blood from the placenta of the mother to the liver of the fetus. After birth, this vein, the ***left umbilical vein***, becomes a fibrous cord, the ***ligamentum teres hepatis*** or ***round ligament of the liver***.

Accordingly, the falciform ligament has the round ligament in its free border; its convex border is attached to the anterior abdominal wall and diaphragm in the median plane; and its concave border is attached to the convex surface of the liver—not in the median plane but—as far to the right of the median plane as the ligament is wide. Hence, the falciform ligament tends to prevent displacement of the liver to the right. Pass a hand backwards on each side of the falciform ligament to where the peritoneum is reflected from the superior aspect of the liver on to the diaphragm, and follow the reflexion to right and left to the respective triangular ligaments, which will be described in a moment (*fig. 273*).

The *left umbilical vein* of prenatal life—which becomes the *round ligament* of postnatal life—extends in the free edge of the falciform ligament from the umbilicus to a notch on the sharp inferior border of the liver; thence it runs sagittally at the bottom of a fissure on the inferior surface of the liver to the left end of the porta. Before birth the left umbilical vein opened for a short time into the left portal vein and, so, poured its blood into the liver. But the necessity for sending through the liver blood that had been purified in the placenta was overcome by the development of another vein, the *ductus venosus*, which serves as a short-circuit or by-pass. It connects the left portal vein to the inferior vena cava, just below the diaphragm (*fig. 232*). The ductus venosus is obliterated after birth and becomes the *ligamentum venosum*. It continues the sagittal course of the umbilical vein, at the bottom of a fissure on the posterior surface of the liver. The fibrous remains of these two obliterated veins can be dissected when the liver is removed or can be seen in a museum specimen. The falciform ligament, the round ligament, and the ligamentum venosum divide the liver into a right and a left lobe.

The *lesser omentum* extends from the lesser curvature of the stomach and first inch of the duodenum to the fissure for the lig. venosum and to the porta hepatis (*fig. 232*).

The *triangular ligaments* are the sharp, bloodless, peritoneal folds at the extreme right and left limits of the attachment of the liver to the diaphragm (*fig. 233*).

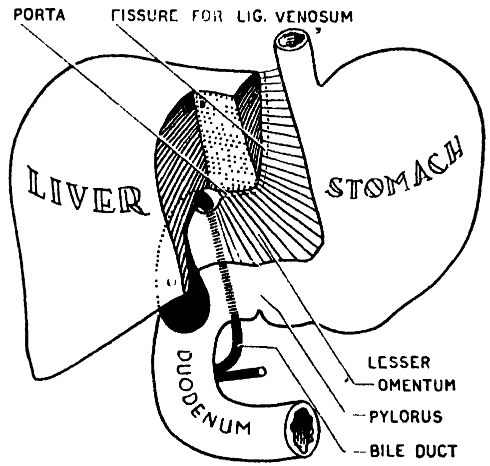


FIG. 232. The attachments of the lesser omentum. (A section has been taken from the liver to show the fissure for the ligamentum venosum.)

They lie at the (diagonally) opposite ends of the posterior surface of the liver. The *left triangular ligament* is an extensive fold which can be clamped between the right index and middle fingers much as can the "pedicle" of the spleen. (Actually, it is attached far back on the upper surface of the left lobe.) The *right triangular ligament* is less well marked. It is attached to the right inferior end of the posterior surface of the right lobe. Its two layers at once diverge and, as the upper and lower layers of the *corondry ligament*, limit the bare area on the back of the liver above

and below. The upper layer of the coronary ligament is reflected from the right lobe of the liver on to the diaphragm. It is continuous with the right layer of the falciform ligament. The lower layer is reflected from the inferior surface of the liver on to the right kidney (and right adrenal gland, and i. v. cava); so, it is synonymously called the *hepato-renal ligament*. Below the hepato-renal ligament there is a peritoneal space, the of the coronary ligament) to the left—the finger keeping contact with the liver —it will slip along the caudate process, above the 1st part of the duodenum, and behind the free edge of the lesser omentum, through the mouth of the lesser sac. Even though you make allowance for the forward curvature of the vertebral column, your finger may catch on the inferior vena cava, which forms the posterior relation of the mouth (*fig. 230*).

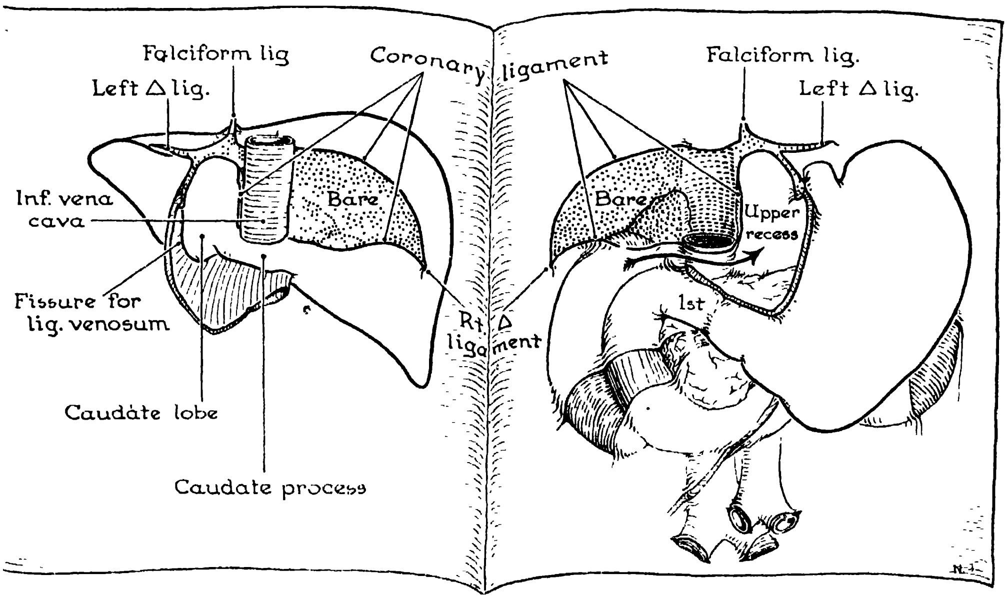


FIG. 233. The coronary and triangular ligaments of the liver. (The attachments of the liver are cut through, and the liver is turned to the left, as you would turn the page of a book. Hence, the posterior aspect of the liver is revealed on the left page and its posterior relations on the right page. The arrow passes through the mouth of the lesser sac.)

hepato-renal pouch of Morison (*fig. 229*). This pouch is bounded ventrally by liver, dorsally by kidney, and caudally by colon and duodenum. It is surgically important: (a) the lesser sac opens into it; (b) the gall bladder and (c) duodenum may rupture into it; and (d) fluid travelling from a ruptured appendix upwards, lateral to the ascending colon, could enter it.

If you run your left index finger along the hepato-renal ligament (lower layer Previously the gall bladder was your guide to the mouth of the sac (page 231).

Pass now the right index finger through the mouth of the sac and upwards in the median plane between diaphragm and liver. The finger is in the upper recess of the lesser sac. This recess, which is large enough to admit two fingers, is limited above, as you can verify, at the falciform ligament; on the left, at the fissure for the ligamentum venosum; and on the right, at the inferior vena

cava, which occupies the left part of the bare area of the liver. Clearly, the right limit of the recess is also the 3rd side or base of the coronary ligament; and the right triangular ligament is the apex. The corona limiting the bare area (that is the area devoid of peritoneum) is therefore not circular but triangular. The area of liver bounding this recess is the *caudate lobe*, or lobe with the tail; the *tail* or caudate process being the narrow isthmus of liver bounding the mouth of the sac above.

The Spleen (continued from p. 232). A thin peritoneal-covered, and easily torn capsule encases the soft, vascular spleen, which is moulded by the structures in contact with it. It is much larger in life. It has a parietal surface in contact with the *diaphragm* and therefore convex; and a visceral surface shared unequally by *stomach*, *kidney*, and *colon*, and therefore subdivided into three concave areas, varying in shape and extent with the degree of distension of these organs, and separated from each other by three rounded radiating borders (*figs. 234, 235*).

The most pronounced feature of the spleen is the notches on its anterior border. This *notched anterior border* is part of the general "circumferential" or "peripheral" border that separates the parietal from the visceral surface. The *hilum* is situated on the gastric surface; vessels and nerves penetrate the hilum; the *pancreas* abuts against it; and the lieno-renal and gastro-splenic ligaments are attached to it. Supporting the spleen is the phrenico-colic ligament.

Surface Anatomy. The spleen lies deep to the 9th, 10th, and 11th left ribs. Its long axis follows the 10th rib and extends from, or almost from, the adrenal gland to the mid-axillary line. Separating it from the ribs are the peritoneal cavity, the diaphragm, and the pleural cavity; in its upper half the left lung also intervenes (*fig. 236*).

Development (*figs. 249, 250*). The spleen develops in the left layer of the primitive dorsal mesogastrium and draws upon the nearest artery to the stomach

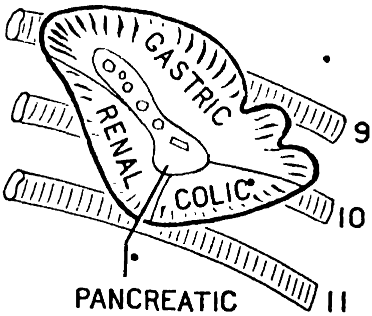


FIG. 234. The visceral surface of the spleen and its "circumferential" border.

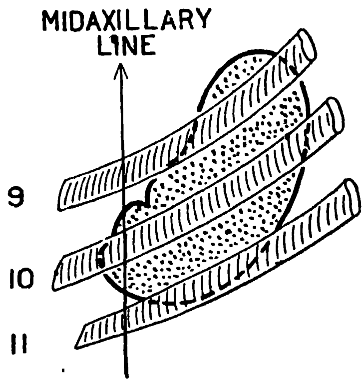


FIG. 235. The parietal (diaphragmatic) surface of the spleen.

for its blood supply. This artery becomes the splenic artery of adult anatomy while the short gastric and left gastro-epiploic arteries come to be described as branches of the splenic artery.

In fetal life the body and tail of the pancreas lie with the splenic artery between the layers of the primitive dorsal mesogastrium and the tip of the tail extends to the spleen. Between the median sagittal plane and the middle of

the left kidney the primitive dorsal mesogastrium is lost; the remainder becomes the lieno-renal and gastro-splenic ligaments (*fig 251*).

Variations. Accessory spleens, the size of large lymph glands, are not uncommon near the spleen between the layers of the gastro-splenic ligament. A fragment of the spleen rarely descends with the testis. Usually there are two notches on the anterior border of the spleen, but there may be more or none.

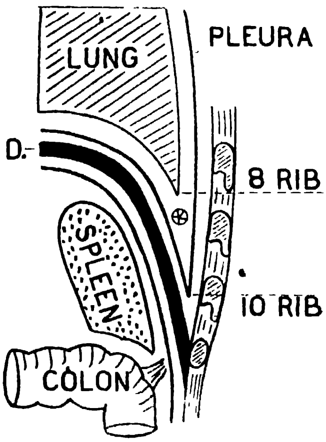


FIG. 236. Coronal section in the midaxillary line. (Star marks the costodiaphragmatic recess.)

Fissures commonly occur on the posterior border and on the diaphragmatic surface.

The Ever Changing Positions of the Abdominal Viscera. The positions of the various abdominal viscera vary considerably from subject to subject, depending largely upon the body build—upon whether the subject is of the broad type (when, characteristically, they are placed high in the abdomen) or of the intermediate and slender types (when they are placed lower) (*fig. 768, 769*). Now, in life the viscera are not stationary, as after death, but are ever changing both their shapes and their positions. They move with the movements of the diaphragm and of the anterior abdominal wall. They move when the posture alters, being highest when the subject is recumbent, lower when he stands, and still lower when he sits—the Transversus Abdominis being then less active (*fig. 237*). They rise when the anterior abdominal wall is voluntarily retracted. The size of the hollow organs (e.g., stomach, intestines, bladder, and uterus) vary as they fill and empty, and they vary with the tone of their muscle coats (e.g., fear and other emotions result in relaxation of the stomach so that the greater curvature suddenly falls). The shapes of the so-called solid organs, particularly the liver and spleen which are virtually soft sponges filled with blood, depend largely upon the degree of distension of the contiguous hollow organs.

The following data are submitted for your appreciation—not for you to memorise. They are based largely upon extensive radiological work done by Moody and Van Nuys on healthy adult male and female students. The *oesophageal orifice* of the stomach, being relatively fixed by the diaphragm, is nearly stationary. The lowest point on the *greater curvature* of the empty stomach, in healthy male students when erect, varies in level from vertebra L. 1 to S. 1, and when supine from Th. 12 to L. 5. (*fig. 238-A*). In any subject it is lowest in the erect posture, and on an average it rises the height of a vertebra on assuming the prone posture (face downwards), and of another vertebra on assuming the supine (face upwards). Similarly, the position of the *pylorus* ranges from the level of L. 2 to L. 5 in the erect posture, and from Th. 12 to L. 4 in the supine (*fig. 238-B*), and horizontally, it ranges between 7 cm. to the right of the median plane and 5 cm. to the left. In any subject, on changing from the erect posture to the supine, it

moves from 2 cm. to 10 cm. (usually 6 cm. to 8 cm.). On changing from the erect posture to the prone, and again from the prone to the supine, it moves upwards and to the right (e.g., in the erect posture tion of its position when standing up; it moves from 1 cm. to 16 cm.

The neck of the pancreas is held firmly between the coeliac and s. mesenteric aa. The *duodenum* and the *head of the pan-*

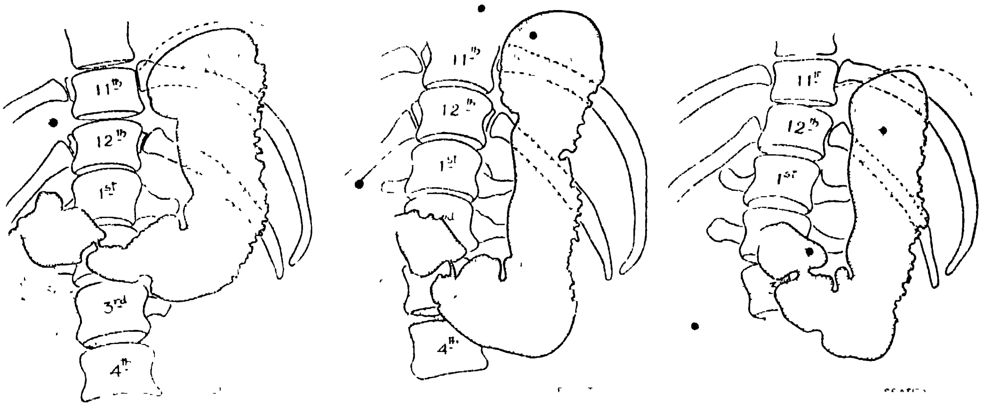


Fig. 237. Tracings of radiograms of the stomach of a healthy female, aged 30 years. (Radiograms by Dr. Keith Bonner.)

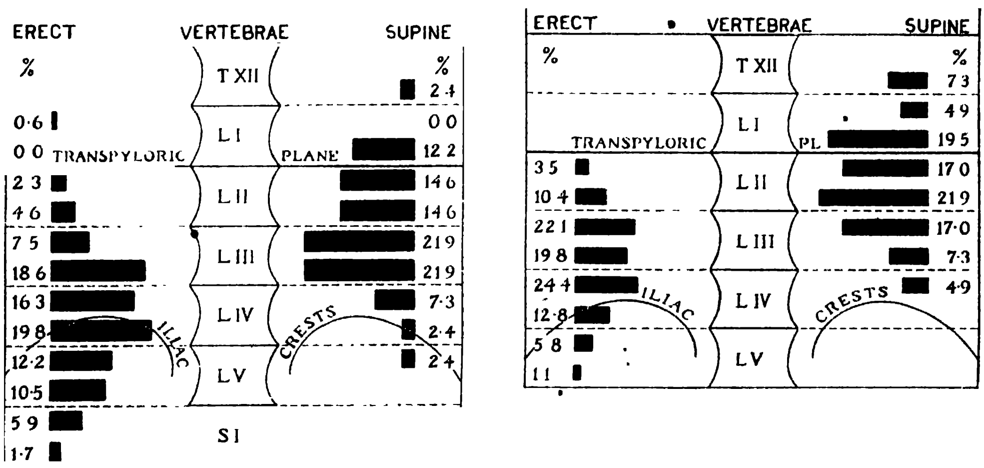


Fig. 238. Right:—Frequency distribution (in percentages) of the relation of the lowest part of the greater curvature of the empty stomach to the vertebral column in healthy adult males (172 erect, 41 supine). Left:—Frequency distribution (in percentages) of the relation of the pylorus to the vertebral column in healthy adult males (86 erect, 41 supine). (Based on the work of Moody, van Nuy's and Kidder.)

34 per cent of pylori are to the left of the median plane, but in the supine only 8 per cent). The greater curvature and the pylorus are usually lower in the female than in the male. The position of the stomach when lying down is no indica- *creas* are suspended from the liver by the bile passages, hepatic a., and portal vein. They can, however, slide downwards on the areolar bed behind them, provided the liver adjusts its shape (*fig. 280*).

The *caecum* in fetal life lies below the

right lobe of the liver; thence it descends to the right iliac fossa. This descent may be incomplete; on the other hand, in 91 per cent of students the lowest part of the caecum is below the iliac fossa. The *transverse colon*, in the erect posture, is most commonly U- or V-shaped, its lowest point most often being 3 to 4 inches below the interiliac line (i.e., a line joining the highest points on the iliac crests).

The liver and spleen also vary in position. The greatest height of the right

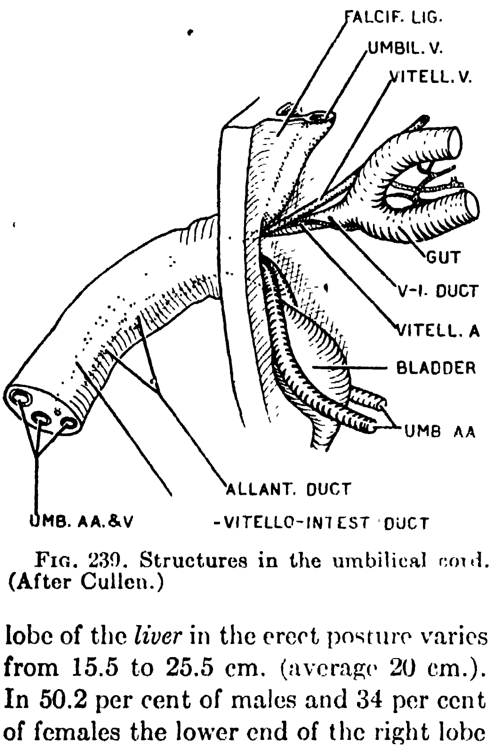


FIG. 239. Structures in the umbilical cord. (After Cullen.)

lobe of the *liver* in the erect posture varies from 15.5 to 25.5 cm. (average 20 cm.). In 50.2 per cent of males and 34 per cent of females the lower end of the right lobe lies below the interiliac line, as much as 5.0 cm. The average excursion made by this lower end, on changing from the erect posture to the supine, varies from 0 cm. to 10.9 cm. (average 2.5 cm.). In the cadaver the lower limit of the *spleen* usually reaches the level of vertebra L. 1; but in the living of both sexes when erect it varies from L. 1 to L. 5 (average L. 3). The spleen is smaller after death, after exercise, and after haemorrhage or after giving blood for transfusion.

The kidneys. The commonest position of both kidneys in both sexes is opposite the upper 4 lumbar vertebrae, when the subject is erect; and opposite the 12th thoracic and upper 3 lumbar vertebrae, when the subject is supine.

With the subject supine, the caudal pole of the right kidney is below L. 3 in 38% of the men and in 48% of the women; whereas this pole of the left kidney is below L. 3 in 17% of the men and only 9% of the women.

The excursion of the kidneys due to forced respiration varied from 0.1 cm. to 6.5 cmm.

In addition to an upward and downward movement of the kidneys, there is a movement of the poles (one or other, or both) to or from the mid-line of the body, ranging from 1 mm. to 25 mm.

The Umbilicus. When the umbilicus or navel is examined from its peritoneal aspect, four fibrous cords are seen radiating from it. They are the obliterated remains of four tubes which in fetal life traversed the umbilical cord (*fig. 239*). They are named, the urachus, the right and left umbilical arteries, and the left umbilical vein. Each of the four may produce for itself a peritoneal fold or mesentery; but whether lying in peritoneal folds or not, they are all situated in the subperitoneal fatty-areolar layer (layer 7) of the anterior abdominal wall, and it would be to no purpose that you search for them in other layers (*figs. 203, 240*).

The *urachus* or *obliterated allantoic duct* ascends in the median plane from the apex of the urinary bladder to the umbilicus. (In the embryo chick the allantoic duct leads to a collapsed, vascular, respiratory sac, called the allantois, which lines the inner surface of the egg

shell.) On each side of the urachus an *obliterated umbilical artery* proceeds from the internal iliac artery to the umbilicus. (In the chick embryo these arteries supply the allantois; so, they are called the allantoic arteries.) In the human embryo the allantois is rudimentary; its duties are assumed by the placenta; and the allantoic arteries become the placental arteries. After birth the umbilical cord is cut and the arteries thereafter become the obliterated umbilical arteries. Hence, the adjectives—allantoic, placental, and obliterated umbilical—record stages in the evolutionary history of these arteries. In adult man, as we shall see, the stem of the obliterated umbilical artery is pervious and sends superior vesical branches to the urinary bladder from which the urachus springs. (Wide of these on each side an inferior epigastric artery passes from the external iliac artery to the rectus sheath—occasionally in a pronounced fold.) Before birth the (*left*) *umbilical vein* returns purified blood from the placenta to the heart via the liver. It runs upwards and backwards from the umbilicus, past the sharp inferior border of the liver, to the porta hepatis, and it occupies the lower free border of the falciform ligament, which indeed is its "mesentery". After the cord is cut at birth, the left umbilical vein becomes obliterated and is thereafter known as the lig. teres hepatis or round ligament of the liver.

If at birth the cord is cut very short (a) urine will escape from the umbilicus, if the urachus is patent; (b) feces, if the vitello-intestinal duct is patent; and (c) the peritoneal cavity will be opened, if the extra-embryonic celom is patent. The intestine may become twisted and strangled. if the vitello-intestinal duct or the vitelline (superior mesenteric) artery remains attached to the umbilicus. The intestinal end of this duct springs from the ileum about two feet from the cecum (*fig. 244*) and remains patent (Meckel's diverticulum) in 2 per cent of persons.

Peritoneal Folds. Peritoneal folds are so commonly *"the mesenteries"* of tubes that they should be treated on the suspicion that they conceal a tube in their free edges. The tubes may be ducts, veins, or arteries; they may be patent or obliterated (*fig. 240*).

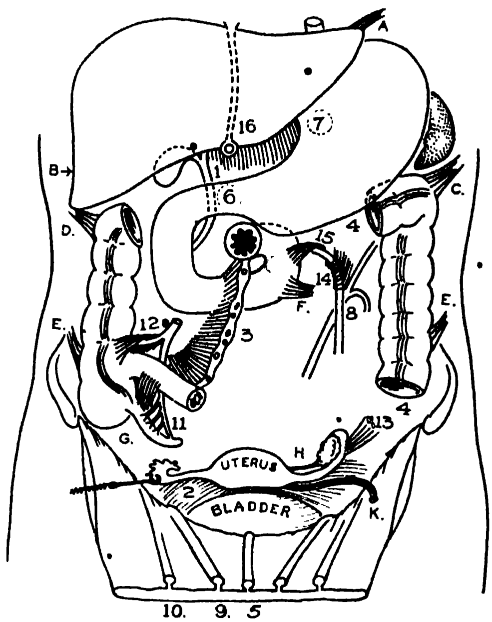


FIG. 240. Peritoneal folds acting as "mesenteries" of tubes (see table 11).

THE FOLLOWING PERITONEAL FOLDS DO NOT CONTAIN TUBES. They are indicated alphabetically in figure 240.

a. Left triangular ligament of the liver.

b. Right triangular ligament of the liver.

c. Phrenico-colic ligament (supporting lig. of the spleen).

d. "Supporting ligament of liver."

e. Acquired folds lateral to the ascending and descending colons.

f. Fold guarding inferior duodenal fossa.

g. Inferior ileo-cecal fold (bloodless fold of Treves, *fig. 241*).

h. Ligament of the ovary (ovario-uterine ligament).

k. Round ligament of uterus.

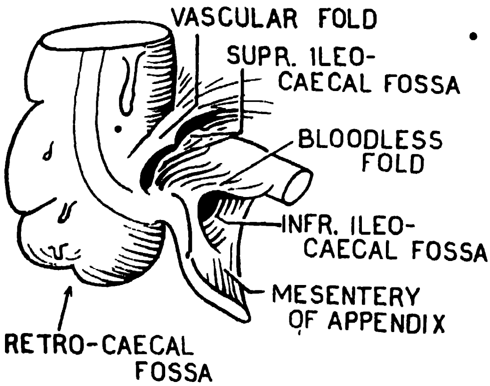


FIG. 241. The peritoneal fossae about the caecum.

Fold between gall-bladder and duodenum (occasional).

Peritoneal Fossae and Recesses and Gutters occur as follows:

1. *Lesser Sac* of peritoneum (omental bursa) with an upper recess behind the caudate lobe of the liver, and a lower recess (commonly partly obliterated) enclosed by the greater omentum.

2. *Above the greater omentum:* The right and left *Subphrenic Spaces* lie between diaphragm and liver, one on each side of the falciform ligament. The *Hepato-renal Pouch* of Morison lies between the right lobe of liver, right kidney, and right colic flexure. When the subject is supine, this is the lowest part of the peritoneal cavity, above the pelvic brim. Hence, free fluid (e.g., from a ruptured gall-

TABLE 11

Peritoneal Folds Acting as "Mesenteries" of Tubes

NATURE OF TUBE	PATENT OR OBLITERATED	NAME OF FOLD	NAME OF TUBE OF WHICH THE FOLD IS A MESENTERY	NUMBER ON FIGURE 240
Duct	Patent	The lesser omentum	The bile passages	1
		The broad ligament of the uterus	The uterine tube	2
		The mesentery	The small intestine	3
		The mesocolon	The large intestine	4
	Obliterated	The median umbilical ligament	The urachus	5
Artery	Patent	The right gastro-pancreatic fold	The hepatic a.	6
		The left gastro-pancreatic fold	The left gastric a.	7
		The fold of the paraduodenal fossa	The asc. branch of left colic a. sometimes	8
	Obliterated	The lateral umbilical ligament	Obliterated umbilical a.	9
Artery and Vein	Patent	The fold of the inferior epigastric vessels	Inferior epigastric vessels	10
		The mesentery of the appendix	Appendicular vessels	11
		The superior ileo-cecal fold	Anterior cecal vessels	12
		The ovario-pelvic ligament	Ovarian vessels	13
Vein	Patent	The fold of paraduodenal fossa	Inferior mesenteric vein	14
		The fold of superior duodenal fossa	Inferior mesenteric vein	15
	Obliterated	Falciform ligament of the liver	Left umbilical vein (or lig. teres)	16

bladder, duodenum, or appendix) tends to gravitate here—if the subject is supine. The "*circumliental pouch*", above the phrenico-colic ligament, is part of the left subphrenic space.

3. *Below the greater omentum* (infracolic) are the following fossae and gutters:

Duodenal Fossae: The superior duodenal, inferior duodenal, paraduodenal, and retroduodenal fossae have a cruciate arrangement. Their mouths face each other and open on the left of the duodeno-jejunal junction. One or more of these is commonly present.

Cecal Fossae: The superior ileo-cecal, inferior ileo-cecal, and retro-cecal fossae are related to the cecum (*fig. 241*). An extensive retro-cecal fossa is a retro-colic fossa.

An Intersigmoid Fossa is sometimes present. Its mouth opens at the apex of the Λ-shaped root of the pelvic mesocolon, where the left ureter crosses the common iliac vessels. A pencil can be pushed up the fossa for one or more inches in front of the ureter.

4. *Pelvic Fossae:* In the male the recto-vesical fossa lies between rectum and bladder. In the female the uterus and its broad ligaments divide the recto-vesical fossa into utero-vesical and recto-uterine fossae.

5. *The "Retro-omental" or Paracolic Gutters* (*fig. 242*): The root of the mesentery and the ascending and descending colons project from the posterior abdominal wall under partial shelter of the greater omentum. As a result there are 4 gutters: (1) The right lateral gutter is placed lateral to the ascending colon and cecum. (2) The left lateral gutter is placed lateral to the descending and pelvic colons. (3) The right medial gutter lies between the root of the mesentery and the ascending colon. (4) The left medial gutter lies between the root of the mesentery and the descending colon. Of these, the right medial is closed above and below. The three others lead directly to the pelvis. The right lateral gutter is the only gutter open above. It would conduct fluid from the hepato-renal pouch and right subphrenic space past the appendix and into the pelvis—if the subject is sitting.

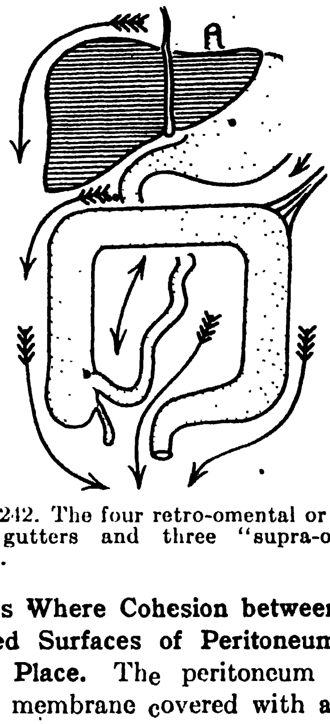


FIG. 242. The four retro-omental or "paracolic" gutters and three "supra-omental spaces".

Areas Where Cohesion between Two Opposed Surfaces of Peritoneum Has Taken Place. The peritoneum is an areolar membrane covered with a layer of squamous cells. It may be likened to a wall covered with wallpaper; the wallpaper (cells) may wear away, but the wall (areolar membrane) persists. The sites where cells die and are not renewed, with resulting cohesion of the opposed areolar surfaces, are enumerated below and partly shown in fig. 247. The surfaces are, so to speak, only gummed together (no vessels, nerves or other structures pass between them)—they may be separated with impunity and restored to their embryological state; and of this the surgeon takes advantage.

1. The portion of the dorsal mesogastrium between the aorta and the middle of the left kidney (*fig. 251*).

2. The mesoduodenum, including the part in which the pancreas is contained (*fig. 252*).

3. The ascending and descending mesocolons.

4. The right portion of the transverse mesocolon adheres to the right kidney, 2nd duodenum, and head of the pancreas (*fig. 276*).

5. The greater omentum adheres to transverse colon and mesocolon (*fig. 252*).

6. The walls of the greater omentum commonly cohere, thereby obliterating the lower part of the lesser sac.

7. The pouch between the prostate and rectum (*fig. 253*).

8. The umbilical celom (part of the extra-embryonic celom).

9. The processus vaginalis peritonei (*fig. 203*).

Morphology of the Peritoneum. Though the peritoneal cavity has been opened, you have refrained so far from tearing or destroying the peritoneum and from using the knife. You have seen, handled, and noted the disposition of such organs and structures as can be examined without dissection; you have noted the various omenta, mesenteries, and ligaments; you have explored the recesses of the peritoneum, and the information you have gained has been first hand.

Now, neither the general relationships already observed nor the more detailed ones to be studied can have an intelligent meaning without some knowledge of the morphology of the peritoneum. You should, therefore, give your attention to the following fundamental facts. After you have done so, and before you proceed to dissect and destroy, you may think it well to review the foregoing chapter in the light of these new facts.

THE CELOM. The peritoneal cavity is, in embryonic life, a portion of a more extensive cavity, called the *celom* or *body cavity*. The celom includes:

(a) Pericardial cavity
(b) Pleural cavities
(c) Peritoneal cavity and its diverticula:
    1. Processus vaginalis { (a) funicular process; (b) tunica vaginalis }
    2. Extra-embryonic coelom { (a) funicular part; (b) placental part }

In embryonic life the pericardial cavity was in open communication with the pleural cavity of each side below the corresponding arch of the azygos vein (duct of Cuvier), and these pleuro-pericardial openings may fail to close. The pleural cavity of each side was in open communication with the peritoneal cavity behind the kidney, and these *pleuro-peritoneal openings* also may fail to close with a resulting congenital diaphragmatic hernia.

The Processus Vaginalis Peritonei is described on p. 214.

The Extra-embryonic Celom extends through the umbilical cord and, spreading out, completely surrounded the amnion and thereby separated it from the placenta and chorion, except at the body stalk. At birth, the part traversing the cord, i.e., the "funicular" part, may remain patent for an inch or so, thereby conducing to a congenital umbilical hernia. The placental or peri-amniotic part becomes obliterated; but, after the birth of a child, the obstetrician, when examining the placenta, deliberately separates the amnion from the chorion and placenta, thereby reopening the peri-amniotic celom.

ABDOMINAL RELATIONS AND PERITONEUM. When considering the relations of one abdominal structure to

another *it is of the first importance to keep the following general embryological facts vividly before you.*

1. The abdomen may be said to exist in order to accommodate:

(a) *The Gastro-intestinal Tract* and its two derivatives, the *liver* and *pancreas,* with which is associated the *spleen.* These you should regard collectively as "the gastro-intestinal tract and the three unpaired glands" or even, if it gives emphasis to the idea of a united system, as "*The G. I. Tract & Co.*".

(b) *The Right and Left Uro-genital Tracts,* including their two paired glands, the *kidneys* and *sex glands* (testes or

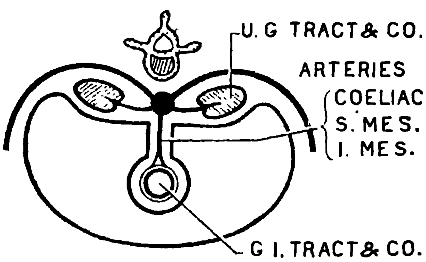


FIG. 243. Transverse section of the abdomen of an embryo (schematic).

ovaries) with which are associated the right and left *adrenal glands.* These you may refer to collectively as the uro-genital tract and the three paired glands; or as "the three paired gland system" or even as the "*The U. G. Tract & Co.*".

2. During early embryonic life the "three paired glands" lay on each side of the aorta, covered with the peritoneum of the posterior abdominal wall. A comparable condition is found in the adult frog.

3. At the same early period the gastro-intestinal canal was a straight tube of uniform calibre, slung from the front of the vertebral column and aorta by a mesentery, the *primitive dorsal mesentery.*

4. Three separate and unpaired branches of the aorta, named the celiac, superior mesenteric, and inferior mesenteric arteries, supplied the gastro-intestinal tract and its three unpaired glands (*figs. 243, 244*). The superior mesenteric artery continued as the *vitelline artery* through the umbilicus to supply the yolk sac.

4a. The portal vein is formed by three unpaired veins, named the splenic (= the celiac), superior mesenteric, and inferior

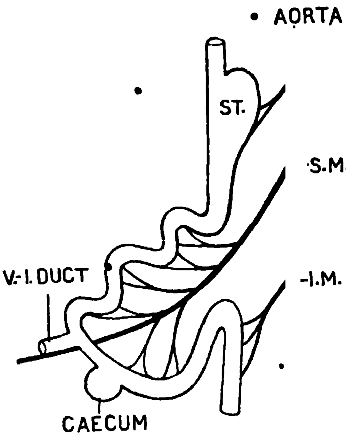


FIG. 244. The three unpaired arteries of the "G. I. Tract & Co." in the primitive dorsal mesentery.

mesenteric veins; so, it returns to the liver the blood that the celiac, superior mesenteric, and inferior mesenteric arteries conveyed to the G. I. Tract and its unpaired glands, the liver, of course, excepted. The portal vein, therefore, receives all the blood returning from the "G. I. Tract & Co." and it receives no other blood (*fig. 245*).

5. The diaphragm is supplied by cervical segments 3, 4, and 5 by way of the phrenic nerves. It developed in the neck. With the advent of lungs, the diaphragm descended, pushing the stomach and celiac artery before it and dragging the phrenic nerves after it.

6. The adult intestinal canal exceeds twenty feet in length, but the abdominal cavity is only two feet long. A time, therefore, must come in fetal life when the gut ceases to be a straight tube confined to the median plane of the body. The small intestine then becomes convoluted; and a long loop of gut, involving the cecum and adjacent parts of the small and large intestine, taking the superior mesenteric artery as an axis, rotates counterclockwise around it. This brings the cecum temporarily to the under surface of the liver. From here it ultimately descends into the right iliac fossa and so helps to encircle the small gut (*fig 246*).

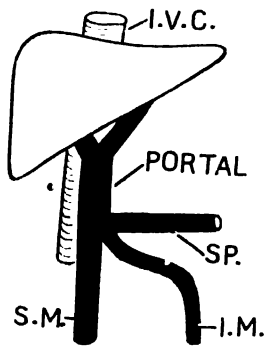


FIG. 245. The three unpaired veins of the "G. I. Tract & Co." form the portal vein.

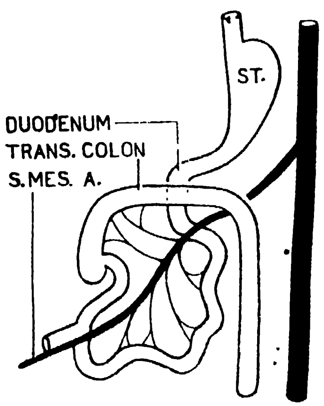


FIG. 246. Rotation of gut around the superior mesenteric artery.

7. Thereafter, the mesenteries of the ascending, the beginning of the transverse, and the descending (including the iliac) portions of the colon, together with any branches of the mesenteric vessels they may contain, adhere to the posterior abdominal wall (*fig. 247*). Just as pages 2 and 3 of an opened book, on falling to the right or left, must come to lie in front of page 1 or page 4, so every part of "the G. I. Tract & Co." that falls to right or left must come to occupy a position ventral to anything and everything pertaining to "the U. G. Tract & Co." it happens to cross; that is, to the adrenals, kidneys, testes or ovaries; to the adrenal, renal, and spermatic vessels; and, to the ureters and vasa deferentia (*fig. 248*). The remainder of the transverse colon and the pelvic colon alone retain mesenteries. The rectum and the anal canal do not become lengthened and, so, are enabled to retain their primitive median positions.

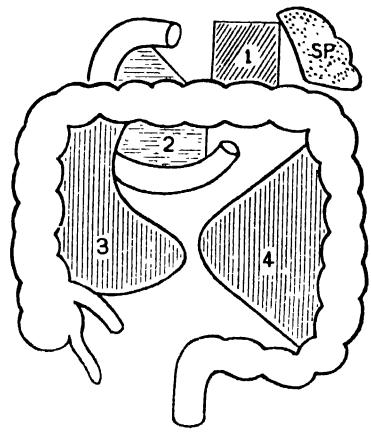


FIG. 247. Sites where primitive mesenteries adhere to the posterior abdominal wall: (1) dorsal mesogastrium, (2) mesoduodenum, (3) mesocolon of ascending colon and right colic flexure, (4) mesocolon of descending colon.

8. The counterclockwise rotation of the gut must bring some part of the large intestine in front of the "superior mesen-

teric arterial axis" and some part of the small intestine behind it. The respective parts happen to be the transverse colon and the 3rd part of the duodenum (*fig. 246*). When the beginning of the transverse colon loses its mesentery, it adheres to the 2nd part of duodenum and head of the pancreas. It is evident that in order to free or mobilize a portion of the colon without damage to its vessels, the peritoneum must be torn through on the outer "rim" of the gut, for the vessels pass from aorta to colon as spokes radiate

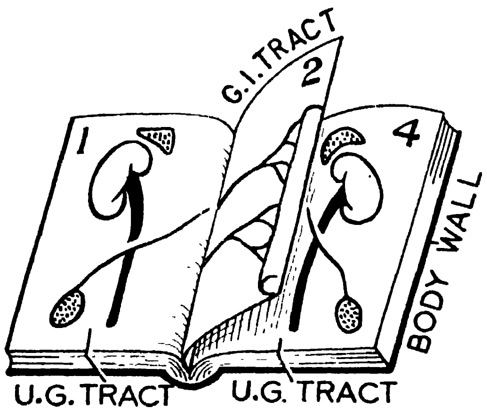


FIG. 248. The pages of a book serve to demonstrate that the "G.I. Tract & Co" is necessarily ventral to the "U.G. Tract & Co."; and the "U.G. Tract & Co." to the body wall.

to the rim of a wheel. In mobilizing, you partially restore the gut to its former embryological state, giving it back its mesentery. For example, to expose the posterior aspect of the 2nd part of the duodenum, you may safely pull the right colic flexure and transverse colon downwards, and swing the duodenum forwards and medially, without damage to vessels or nerves (*fig. 280*).

9. The transverse colon would seem to have forced the entire duodenum (save its 1st inch) and the pancreas, which lay in the meso-duodenum, against the posterior abdominal wall; for the duodenum has lost its mesentery.

10. In addition to the primitive dorsal mesentery, which may be subdivided into as many parts as is found convenient (e.g., mesogastrium, mesoduodenum, mesojejunum, and the various mesocola) there is a *primitive ventral mesentery*. It exists only above the umbilicus and 1st inch of duodenum, so it is better called the *ventral mesogastrium*. The liver divides it into two portions, the falciform

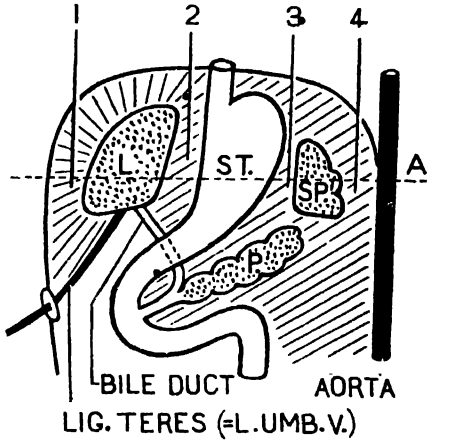


FIG. 249. Primitive ventral and dorsal mesogastria give rise to: (1) falciform lig., (2) lesser omentum, (3) gastro-splenic omentum, (4) lieno-renal lig.

ligament and the gastro-hepatic omentum. The left umbilical vein lies in the free edge of the one, the bile ducts in the free edge of the other; so, the two portions may be regarded as "the mesentery of the umbilical vein (lig. teres)" and "the mesentery of the bile ducts" respectively (*fig. 249*).

The liver divides the ventral mesogastrium into (a) Falciform ligament and (b) Lesser omentum.

The spleen divides the *dorsal mesogastrium* into (a) Gastro-splenic omentum and (b) Lieno-renal ligament.

11. The liver comes to occupy espe-

cially the right side of the body, and relegates the stomach and spleen to the left (*figs. 250, 251*). In accordance with fundamental principles these three organs, belonging to the G. I. Tract and Co., must lie in front of the right and left three paired gland system; the liver being in front of right kidney and adrenal; the

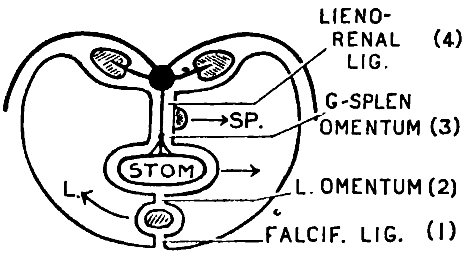


FIG. 250. Transverse section of abdomen of embryo at level A, figure 249, indicating that the liver moves to the right; the stomach and spleen to the left.

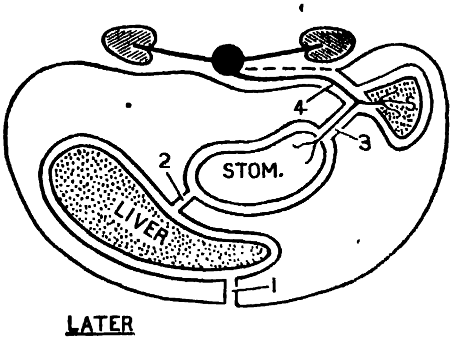


FIG. 251. A later stage than figure 250. Partial absorption of dorsal mesogastrium; the unabsorbed part is the lieno-renal lig.

stomach and spleen in front of the left kidney and adrenal; and, also in front of the testes or ovaries, if they fail to descend.

12. The portion of the dorsal mesogastrium passing between spleen and aorta (it might be called lieno-aortic ligament) is forced against the posterior abdominal wall; and the epithelium lining the opposed surfaces is absorbed, leaving two areolar layers of peritoneum free to adhere to each other between the median plane and the front of the kidney. In view of this new attachment the "lieno-aortic" ligament becomes the *lieno-renal ligament.* If you wish to free or mobilize the spleen, you may open up the dotted line in figure 251 and restore the entire "lieno-aortic" ligament without damage to the splenic vessels or to any other structures.

13. The lesser sac: When the stomach and spleen moved to the left, dragging their peritoneal attachment after them, the lesser sac began to take form. The

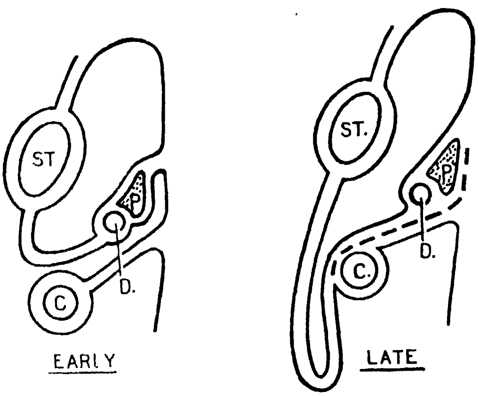


FIG. 252. Development of the greater omentum.

duodenum, by losing its mesentery and adhering to the posterior abdominal wall, limited the mouth of the sac below; the liver, by enlarging, encroached on the mouth, narrowing it from above; and the bile ducts, passing from duodenum to liver in the free edge of the lesser omentum, limited the mouth in front.

14. The primitive lesser sac was at first limited below by the dorsal mesogastrium, but in time it bulged downwards in front of the transverse colon and transverse mesocolon, and adhered to them, thereby forming the greater or gastro-colic omentum. Developmentally, therefore, the transverse mesocolon is four layers thick (*fig. 252*).

15. The portion of the peritoneal cavity between the base of the bladder and prostate anteriorly and the rectum posteriorly undergoes obliteration. And, it is safe to open it up (*fig. 253*).

16. When the stomach moved to the left, it underwent a rotation on its long axis. As a result, its original left surface becomes the ventral surface; the original right surface, the dorsal surface. Hence, the left vagus nerve is to be looked for on the ventral surface of the stomach; the right nerve, on the dorsal surface.

Afferent Nerves of the Peritoneum. These travel as follows: (a) from the

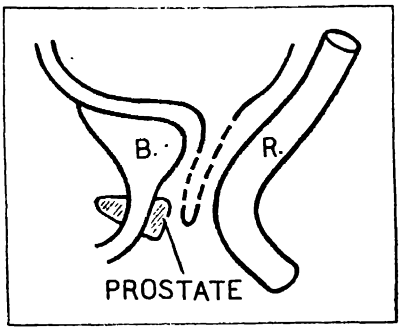


FIG. 253. The posterior aspect of the prostate was formerly extraperitoneal. Obliteration of the "recto-prostatic" peritoneal fossa takes place along the broken line.

central parts of the diaphragm via the phrenic nerve (C. 3, 4, 5); direct mechanical stimulation of this area causes pain referred by the supraclavicular nerves (C. 3, 4) to the lower part of the anterior border of the Trapezius; (b) from the *peripheral parts of the diaphragm* via the intercostal and subcostal nerves (Th. 7–12); here stimulation causes pain referred through these same nerves to the skin of the abdominal wall; (c) from the *parietal peritoneum* again via these same nerves (Th. 7–12) and L. 1; here stimulation is correctly localised at the point stimulated; (d) the mesenteries of the small and large intestines are sensitive from their roots to near the intestine, whereas the *greater omentum* and the *visceral peritoneum* are insensitive to mechanical stimulation (Morley). In the mesentery, free endings of myelinated nerves persist after section and degeneration of vagus and splanchnic fibres. Evidently these endings are responsible for the sensitivity of the mesentery, and presumably they are derived from the somatic nerves supplying the parietal peritoneum (Sheehan).

THE LESSER OMENTUM; THE BILE DUCTS; THE CELIAC ARTERY; THE PORTAL VEIN; THE STOMACH, AND THE INFERIOR AND POSTERIOR SURFACES OF THE LIVER.

You have studied the peritoneum and the disposition of the abdominal viscera in so far as can be done without dissection. You must now be prepared to destroy the peritoneum by degrees as the examination proceeds.

The Lesser Omentum extends from the lesser curvature of the stomach and first inch of the duodenum to the fissure for the ligamentum venosum and to the porta hepatis (*fig. 232*), and in its free edge runs the cystic duct. *The cystic duct* is to be traced from the neck of the gall bladder to a point 1.0 cm. above the first part of the duodenum where it unites at an acute angle with the common hepatic duct to form the bile duct. Later the bile duct will be followed behind the first part of the duodenum and the head of the pancreas to the second part of the duodenum which it enters 3 inches from the pylorus (*fig. 254*). The common hepatic duct is formed in the porta hepatis by the union of the right and left hepatic ducts, and is bound to the cystic duct by a tough areolar web. On the

medial side of these ducts lies the hepatic artery; and behind the ducts and artery lies the thin-walled portal vein. Accompanying these are lymph vessels, branches of the vagus, and branches of the celiac plexus.

While cleaning these structures, a finger, or as a substitute a roll of paper, may be passed through the *mouth of the lesser sac* of peritoneum (epiploic foramen) to guard the i. v. cava which is the

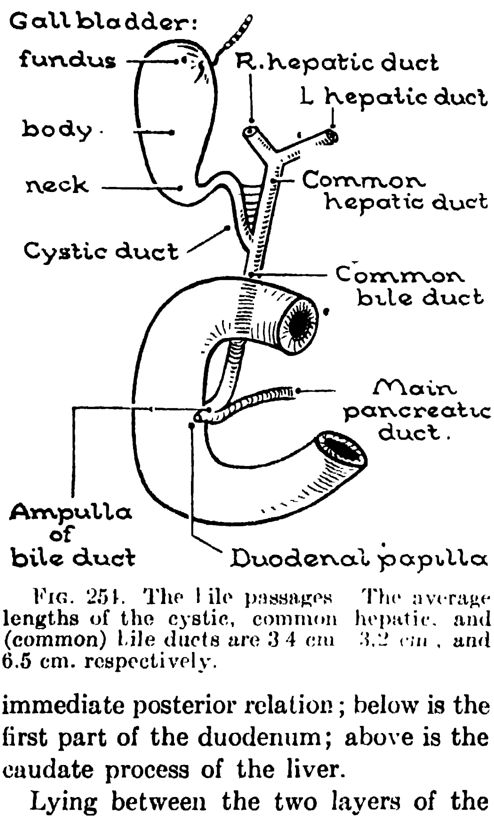


FIG. 251. The bile passages The average lengths of the cystic, common hepatic, and (common) bile ducts are 3 4 cm 3.2 cm, and 6.5 cm. respectively.

immediate posterior relation; below is the first part of the duodenum; above is the caudate process of the liver.

Lying between the two layers of the lesser omentum along the lesser curvature of the stomach are the right and left gastric arteries with their accompanying veins, lymph vessels and lymph glands, and branches of the gastric (vagus) nerves.

The Celiac Artery is the first of the 3 unpaired arteries that supply the gastrointestinal tract (*fig. 244*). Access to the celiac artery, pancreas, and other structures behind the lesser sac may be had by three routes: by cutting through (1) the lesser omentum or (2) the transverse mesocolon or (3) the greater omentum (*fig. 231*). By way of the *lesser omentum* access is somewhat limited; by way of the *transverse mesocolon* it is good, but the middle colic artery, which runs in the mesocolon, must first be identified and preserved; by way of the *greater omentum* access is excellent—the cut should be made an inch below the greater curvature thereby avoiding the stems of the gastro-epiploic vessels, though severing their epiploic (omental) branches. Since the transverse mesocolon is applied to the greater omentum, the middle colic artery is in danger even by this route.

SURFACE ANATOMY AND RELATIONS. The celiac artery springs from the aorta between the crura of the diaphragm which, so to speak, sit astride it. The pancreas lies below it. Now, the diaphragm, which is the partition between the thorax and the abdomen, happens to descend in the median plane posteriorly to the level of the disc between the last thoracic and the first abdominal (lumbar) vertebra. On the surface of the body this point is, of course, the depth of a vertebra and disc (say $1\frac{1}{2}$ inches) above the transpyloric plane; and it also marks the celiac artery. The stem of the artery is half-an-inch long. It is surrounded by the celiac plexus of nerves, wide of which are the tough, nodular, celiac ganglia, and wide of these again are the adrenal glands, the medullae of which are derived from the celiac ganglia. A stout and strong branch of the posterior gastric nerve, containing fibres from both vagi, descends along the left gastric a. to the celiac plexus; the greater and lesser splanchnic nerves, pierce the crura of the diaphragm and end in the celiac ganglia (*p.* 293 *and fig. 284*).

DISTRIBUTION AND BRANCHES. It is the duty of the celiac artery to supply the stomach, the adjacent parts of the oesophagus and duodenum, and the three unpaired glands --liver, pancreas, and spleen (*fig. 255*). It has 3 branches:

(1) Left Gastric:
 oesophageal
 gastric
 (accessory hepatic)

(2) Splenic:
 pancreatic
 splenic
 short gastric
 left gastro-epiploic

(3) Hepatic:
 gastro-duodenal:
  supra- and retro-duodenal
  right gastro-epiploic
  superior pancreatico-duodenal
 right gastric
 right hepatic and cystic branch
 left hepatic

The Left Gastric Artery is the smallest branch. It ascends on the diaphragm towards the oesophageal orifice and, when a little short of it, arches forwards to reach the lesser curvature of the stomach. In so doing, it drags downwards a fold of peritoneum (the left gastro-pancreatic fold) as a "mesentery".

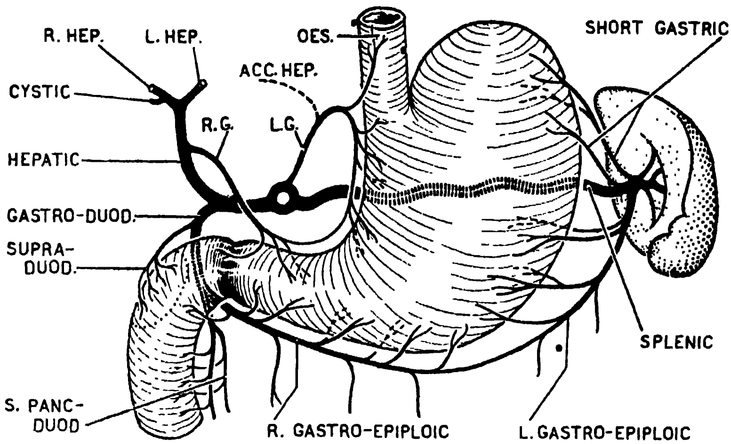


FIG. 255. Distribution of the coeliac artery.

Branches. Its branches are *gastric*, which runs downwards in contact with the lesser curvature and anastomoses with the right gastric; *oesophageal*, which runs upwards through the oesophageal orifice in the diaphragm to anastomose with the oesophageal branches of the thoracic aorta; and, not uncommonly, an *accessory hepatic branch* which passes between the layers of the lesser omentum to enter the liver via the fissure for the ligamentum venosum. In this circumstance the fissure becomes, as it were, a "porta hepatis minor".

The Splenic Artery is the largest branch. It takes a serpentine course to the left along the upper border of the pancreas. It crosses in turn the left crus, the left adrenal gland, and half the breadth of the left kidney. It then passes through the lieno-renal ligament and enters the hilum of the spleen as several branches.

Branches. It sends *pancreatic branches* to the body and tail of the pancreas; several *short gastric branches*, which pass through the gastro-splenic omentum to

the fundus and greater curvature of the stomach; and the *left gastro-epiploic branch*, which also passes through the gastro-splenic omentum into the greater omentum and gradually approaches the greater curvature of the stomach along which it runs, but never closer than a finger's breadth to it. As its name indicates, it sends *gastric* branches to the stomach and *epiploic* (i.e., omental) branches to the greater omentum.

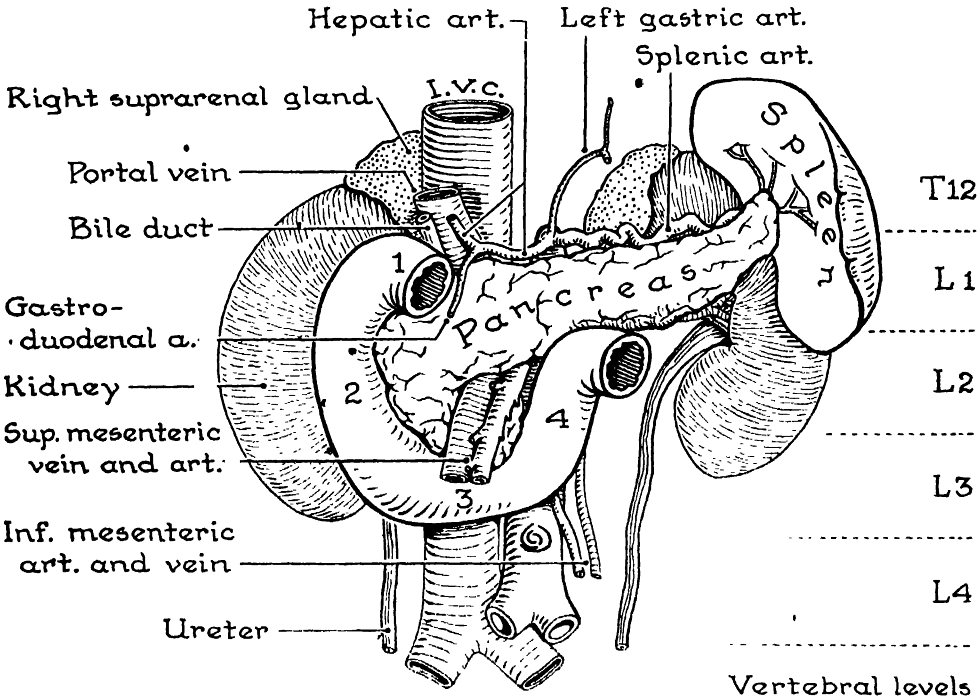


FIG. 256. Abdominal viscera and vessels.

The Hepatic Artery takes a more sober course to the right along the upper border of the pancreas and, like the left gastric artery, creates for itself a little "mesentery" (the right gastro-pancreatic fold), which conducts it in front of the portal vein to the lesser omentum. Thereafter, it ascends in front of the portal vein, and on the left of the bile passages.

Terminal Branches. In the porta, the hepatic artery ends by dividing into the right hepatic a. and the left hepatic a. These enter the corresponding lobes of the liver. The right hepatic a. crosses either in front of or behind the right hepatic duct to reach the porta (*fig. 257*). The *cystic a.* arises from the right hepatic a. or from any nearby artery and ramifies both on the free and on the attached surface of the gall bladder.

Of its *Collateral Branches* (a) the *right gastric artery* arises at some distance above the duodenum and, so, requires to make with the main artery a "hair-pin" bend in order to descend to the lesser curvature of the stomach. (b) The *gastro-duodenal artery* takes origin in front of the portal vein. It passes downwards between the 1st part of the duodenum and the pancreas, where, after a course of ½–1 inch, it divides into the

right gastro-epiploic and the *superior pancreatico-duodenal artery*.

The gastro-duodenal a. gives off an end-artery, the *supraduodenal a.* (Wilkie), to the upper border and adjacent parts of both surfaces of the first part of the duodenum, and *retro-duodenal twigs* to the back of the duodenum as it crosses it.

The right gastro-epiploic a. runs between the two layers of the greater omentum, a finger's breadth from the greater curvature of the stomach, and anastomoses with the left gastro-epiploic a. Both vessels have *gastric* branches and long slender *epiploic* branches, which descend in the omentum.

The superior pancreatico-duodenal a. effects a double arch with the pancreatico-duodenal branch of the superior mesenteric a. (*fig. 278*), one arch lying in front of the pancreas, the other behind it.

Anastomoses. To deprive the liver altogether of its arterial blood is fatal. There is however a *collateral anastomosis.* Thus: (a) the larger branches and the precapillaries of the right and left hepatic aa. anastomose so excellently in the fissures of the liver and deep to the capsule that fluid injected into the one artery flows from the cut end of the other. (b) If the common hepatic a. is ligated, the arterial supply to the liver may yet be assured in those 12% of persons in whom the right hepatic a. arises from the superior mesenteric a. (*fig. 257*). (c) If the hepatic artery is obstructed gradually on the aortic side of the origin of the right gastric a., the circulation is maintained by the anastomosis the right gastric a. effects with the left gastric a. and by means of an occasional accessory hepatic branch of the left gastric (*fig. 255*). The inferior phrenic aa. also send twigs to the liver. The deep intrahepatic aa. are end-arteries.

The Portal Vein drains all and it drains only the gastro-intestinal tract and the 3 unpaired glands, the liver of course excepted. It returns to the liver the blood that the celiac, superior mesenteric, and inferior mesenteric arteries conducted to these parts. The portal vein is formed between the head and neck of the pancreas by the union of the splenic (which represents the celiac artery), the superior mesenteric, and the

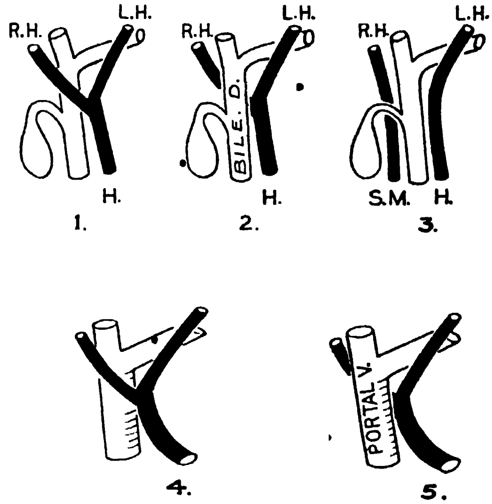


FIG. 257. Variations in the course of the right hepatic artery in 165 specimens:
(1) anterior to bile duct...... 24%
(2) posterior to bile duct 64%
(3) arising from superior mesenteric artery........... 12%
} 100%
(4) anterior to portal vein.... 91%
(5) posterior to portal vein... 9%
} 100%

inferior mesenteric veins. It ascends to the right end of the porta where it divides into the right and left portal veins. The right vein enters the right lobe; the left vein passes transversely to the left end of the porta and supplies the caudate, quadrate, and left lobes.

The portal vein ascends behind the neck of the pancreas, 1st part of the duodenum, and the gastro-duodenal a. It then enters the lesser omentum, where the bile passages and hepatic artery lie in front of it. Behind it lies the i. v. cava—

but intervening are: (a) two dense areolar membranes, one covering the i. v. cava, the other covering the portal vein (*fig. 280*), also (b) peritoneum at the mouth of the lesser sac, and above this (c) the caudate process of the liver.

During dissection, these membranes are the salvation of the i. v. cava; for they make separation without injury feasible.

TRIBUTARIES. In addition to the splenic, superior mesenteric, and inferior mesenteric veins, the portal vein receives the right and left gastric veins. The cystic vein ends in the right portal vein. The ligamenta teres and venosum are

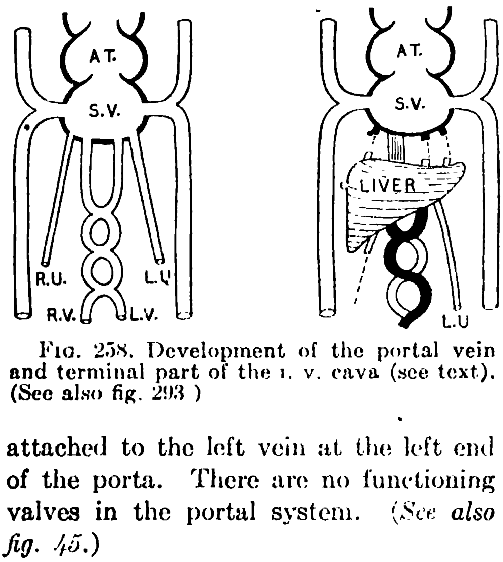


FIG. 258. Development of the portal vein and terminal part of the i. v. cava (see text). (See also fig. 293)

attached to the left vein at the left end of the porta. There are no functioning valves in the portal system. (*See also fig. 45.*)

The Accessory Portal System (Collateral Circulation of the Portal Vein). When the portal vein is slowly obstructed, as a result of disease of the liver or from other causes, the portal blood may enter the systemic veins by way of certain anastomotic veins, which then become dilated and varicose—and they may burst. They are as follows:

(a) At the upper end of the gastro-intestinal tract, the oesophageal branches of the left gastric vein anastomose with oesophageal branches of the azygos veins. (When varicose they are called "oesophageal piles".)

(b) At the lower end of the gastro-intestinal tract, the superior rectal (haemorrhoidal) vein anastomoses with the middle and inferior rectal veins and with the pelvic venous plexuses (p. 348). (When varicose, the rectal or haemorrhoidal veins are called "haemorrhoids or piles". Gk. Haima = blood, Rhein = to flow.)

(c) Para-umbilical veins pass from the porta hepatis along the ligamentum teres to the umbilicus where their branches radiate and anastomose with veins of the body wall. (When dilated they resemble the Caput Medusae.)

(d) Veins at the bare area of the liver and in the falciform ligament anastomose with veins of the diaphragm and body wall.

(e) Twigs of the colic veins anastomose in the extraperitoneal fat with twigs of the renal vein and with veins of the body wall.

Development of the Portal System. In prenatal life the *right* and *left vitelline veins* from the yolk sac and the *right* and *left umbilical veins*, originally from the allantois but later from the placenta, opened independently into the common sinus venosus of the heart (*fig. 258*) until the developing liver intercepted them and broke them up into the anastomosing sinusoids of the liver. Thereafter, the prehepatic parts of the right umbilical, left vitelline, and left umbilical veins disappeared, leaving only the prehepatic part of the right vitelline to conduct blood from the liver to the heart. [Prehepatic = cephalad to the liver; posthepatic = caudad to the liver.] Definitively, this prehepatic part of the right vitelline vein becomes the terminal segment of the i. v. cava (*fig. 293*). It may be this fact that determines that the

right side of the heart shall be the venous side and the left side the arterial side. It certainly explains the close connection between the i. v. cava and the posterior surface of the liver. The posthepatic part of the right umbilical vein disappeared, leaving the corresponding part of the left umbilical vein to bring from the placenta to the liver blood revived with oxygen and laden with products of digestion elaborated by the mother. Apparently it was unnecessary that these should circulate through the liver of the fetus, because a short cut, called the *ductus venosus*, connected the left umbilical vein with the prehepatic part of the right vitelline vein and thereby excluded the portal circulation.

The right and left vitelline veins made a figure-of-8 anastomosis around the 1st and 3rd parts of the duodenum. Out of this the portal vein took form by the disappearance of the posterior (right) limb of the 8 below and of the anterior (left) limb of the 8 above. It is joined by the superior mesenteric, inferior mesenteric, and splenic veins. The parts of the vitelline veins cephalad to the figure-of-8 became the right and left portal veins (*fig. 270*).

The Stomach has 2 orifices, 2 surfaces, and 2 borders or curvatures. The left two-thirds are the fundus and body, the right one-third the pyloric antrum and pyloric canal (*figs. 218, 219*). Its size at birth about equals that of an adult gall bladder. Attached to the lesser curvature and 1st inch of duodenum is the lesser omentum; attached to the greater curvature and 1st inch of duodenum are the gastro-splenic and greater omenta.

Surface Anatomy. The *oesophageal orifice* is situated one inch to the left of the median plane deep to the 7th costal cartilage at the level of the body of the 10th thoracic vertebra or 9th thoracic spine. The *pylorus* in the cadaver lies in the transpyloric plane one inch or less to the right of the median plane. The *shape* and *position*, however, as learned from x-ray pictures are in health highly variable (*fig. 238*). The oesophageal end (the cardia) is fixed to the diaphragm; the pylorus, duodenum, and head of the pancreas can slide extensively on the subjacent areolar sheet—provided the pliable liver, from which they are suspended by the bile passages, hepatic artery, and portal vein, by altering its shape, permits (*fig. 280*).

STRUCTURE. The coats of the stomach are: serous, subserous, muscular, submucous, and mucous. A subserous vein, the *pyloric vein* of Mayo, marks the site of the pylorus in front. It drains either upwards into the right gastric vein or downwards into the right gastro-epiploic.

The muscle coat has three layers—an outer longitudinal, a middle circular, and an inner oblique (*fig. 259*). *The longitudinal fibers* are continuous with those of the oesophagus; they are best marked along the curvatures; at the pylorus they dip in to join the sphincter and only a few are continuous with those of the doudenum. The *circular fibers* are present everywhere except at the fundus, and they are greatly increased at the pylorus to form a sphincter. At the pylorus and anus powerful sphincters are required to keep the contents from escaping from the stomach and rectum respectively. A sphincter is not required to retain food in the oesophagus; in fact anatomically the presence of a sphincter at the oesophageal or cardiac end of the stomach is disputed; perhaps the diaphragm suffices. Physiologically, however, there is a cardiac sphincter which opens on stimulation of the vagus and closes on stimula-

tion of the sympathetic. The *oblique fibers* form ∩-shaped loops that extend over the fundus and down both surfaces of the stomach to the pyloric antrum, the cardiac notch forming their medial limit.

Stratified squamous epithelium lines the oesophagus and upper parts of the food passages. At the cardiac orifice it gives place to the *columnar epithelium* of the digestive part of the alimentary tract.

The mucous membrane is rugose when the stomach is empty and three or four uninterrupted ridges lie along the lesser curvature from oesophagus to pylorus forming a gutter, the "*magenstrasse*".

THE ARTERIES of the stomach are derived from the celiac a. The right and left gastric aa. form an arcade close to its lesser curvature; the right and left gastro-epiploic aa. form an arcade at some distance from its greater curvature and the left artery recedes farther from the stomach as it is traced to the left. Three or 4 short gastric aa. pass to the greater curvature at the fundus via the gastro-splenic omentum (*fig. 255*).

All arterial branches supplying the stomach penetrate the muscle coats and enter the submucosa where they form a very extensive network of comparatively large vessels. From this network in the submucosa two systems of branches are given off. Of these, one turns back to the muscle coats; the other continues on to the mucosa. The branches to the mucosa usually divide twice, run spirally towards the muscularis mucosae, and pierce it to enter the mucosa where they suddenly become smaller by giving off end-branches (i.e., vessels connected only by means of a capillary network). Each end-artery continues to run a spiral

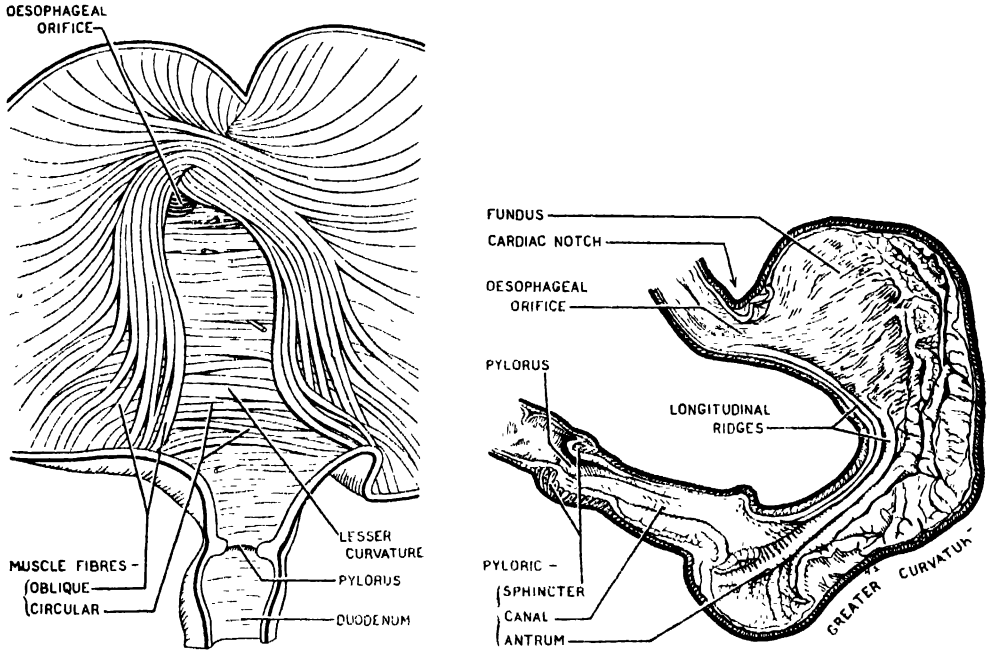


FIG. 259. Left: The muscle coat of the stomach seen from within. (The stomach was opened along the greater curvature and the mucous and submucous coats were removed.) Right: The mucous coat of the posterior half of the stomach.

course, and supplies an area of mucosa of about 2.5 mm. in diameter. The submucous network on the lesser curvature is made up of long parallel vessels which are smaller, make fewer anastomoses, and run more than twice the distance of similarly sized vessels in other parts of the stomach (Reeves).

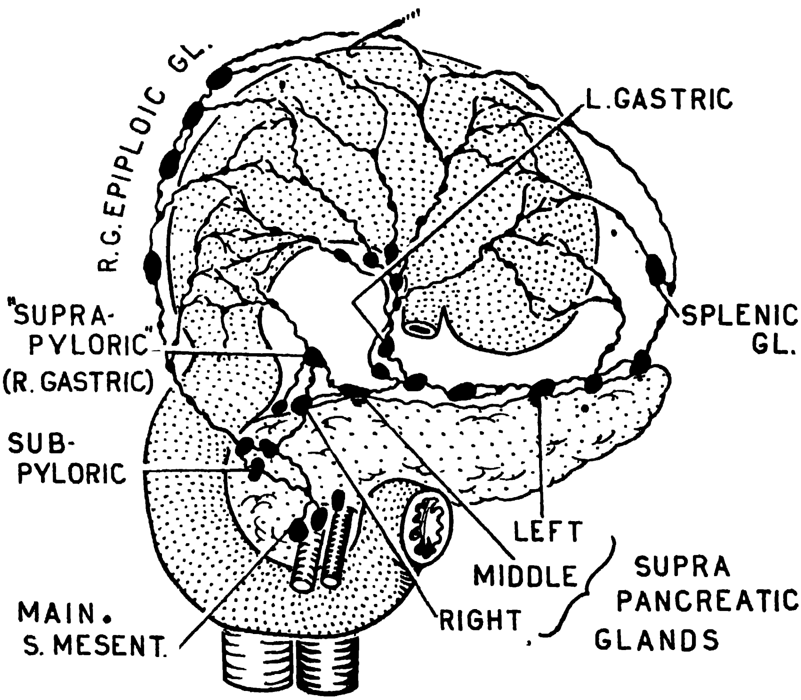


FIG. 260 Lymphatics of the upper abdomen; particularly those of the stomach. (The stomach has been turned up.)

THE LYMPH PLEXUSES OF THE STOMACH, as of other organs, lie in the areolar coats. The upper two-thirds of both surfaces drain into glands beside the left gastric a. on the lesser curvature, thence to glands on the stem of the left gastric a. The lower one-third of both surfaces drain into glands beside the right gastro-epiploic a., thence to glands (subpyloric) in front of the head of the pancreas on the stem of the gastro-duodenal a. The lymph vessels of the left portion of the stomach follow the short gastric and left gastro-epiploic aa. to the hilum of the spleen, thence they follow the splenic a. They are intercepted by glands at the hilum of the spleen and on the course of the splenic artery (*fig. 260 and p. 305*).

NERVES. Owing to the rotation the stomach has undergone, the *anterior gastric nerve* (left vagus) enters the abdomen in front of the esophagus, the *posterior gastric nerve* (right vagus) behind it. Both run close to the lesser curvature and send branches to the respective anterior and posterior surfaces as far as the pyloric antrum.

The *anterior gastric nerve* sends fibers curving upwards in the lower part of the lesser omentum to the porta hepatis, and it is through these branches that the pylorus and first part of the duodenum are supplied.

From the posterior gastric nerve a

branch descends with the left gastric artery to the *celiac plexus* whence, in company with sympathetic fibers, it is distributed along the branches of the aorta to the abdominal viscera, e.g., intestines (proximal to the left colic flexure), pancreas, and spleen and kidneys. This is the only connection these organs have with the vagus nerves.

Sympathetic fibers from Th. 6, 7, 8, via the splanchnic nerves and celiac ganglia, pass to the stomach along the blood vessels.

RELATIONS OF THE STOMACH. Antero-superiorly are: the left lobe of the liver, diaphragm, and anterior abdominal wall. The diaphragm separates it from the left lung and pleura and from the apex of the heart. Its postero-inferior surface lies on "the stomach bed" formed to the extent shown in figs. 261, 273, 275 by:

a. "G. I. Tract and Co."—Transverse colon, transverse mesocolon, pancreas, spleen, celiac artery and its 3 branches.

b. "U. G. Tract and Co."—L. adrenal gland and kidney (between aorta and left adrenal and therefore in front of left crus are the celiac plexus and ganglion and great splanchnic n.). *(See fig. 290.)*

c. Abdominal wall.—Diaphragm.

The Liver—Inferior and Posterior Surfaces. The inferior or visceral surface faces downwards, to the left, and backwards. It is covered with peritoneum of the greater sac and bears the imprint of the viscera that are everywhere in contact with it. The posterior surface faces the diaphragm and is but indistinctly separated from the inferior surface.

An H-shaped series of fissures or fossae subdivides each of these two surfaces into three. The cross-bar of the H is the *porta hepatis;* the quadrilateral area in front of it is the *quadrate lobe;* the quadrilateral area behind it is the *caudate lobe.* The left limbs of the H are deep fissures containing the obliterated left umbilical vein (lig. teres hepatis) and the obliterated ductus venosus (lig. venosum). Since in fetal life the left umbilical vein returned the placental blood to the left portal vein, which distributed it through the liver until the ductus venosus appeared and short-circuited it from the left portal vein to the i. v. cava, it is but natural that the fissures in which these two veins lie should join the left extremity of the porta. They separate the left lobe of the liver from the quadrate and caudate lobes. The right limbs of the H are grooves or fossae for the lodgment of the gall bladder and i. v. cava. Since the duct of the gall bladder occupies the right, free margin of the lesser omentum, it is but natural that the fossa for the gall bladder should lead to the right extremity of the porta. The fossa for the i. v cava, however, fails to meet the porta by the width of the roof of the mouth of the lesser sac, i. e., —the caudate process or tail of the caudate lobe. The caudate process is bounded by the portal vein anteriorly and by the i. v. cava posteriorly; it connects the caudate lobe to the inferior surface of the right lobe proper. *(Fig. 262.)*

THE POSTERIOR SURFACE cannot be seen until the liver has been removed from the body. On the left, it is covered with peritoneum of the greater sac and is grooved by the esophagus. In the median plane, it forms the caudate lobe, which is covered with peritoneum of the lesser sac, and it is separated from the last two thoracic vertebrae by the diaphragm and thoracic aorta. Hence, this is the most deeply concave part of the posterior surface of the liver. On the right, it is destitute of peritoneum and bare. This bare area is bounded by the

three layers (upper, lower, and left) of the coronary ligament. The i. v. cava occupies the left most portion of the bare area; the kidney and adrenal gland encorach on it from below (*fig. 263*).

THE INFERIOR SURFACE. From the accompanying figures it is seen that the esophagus is in contact with the attenuated posterior surface of the left lobe from below, nor the entire quadrate lobe. The transverse colon, which you have seen in front of the 2nd part of the duodenum, runs from right to left behind the sharp, inferior margin of the liver as far as the median plane, and leaves its impress on the right lobe, gall bladder, and quadrate lobe. Behind these intestinal areas the right lobe is hollowed for the right kidney

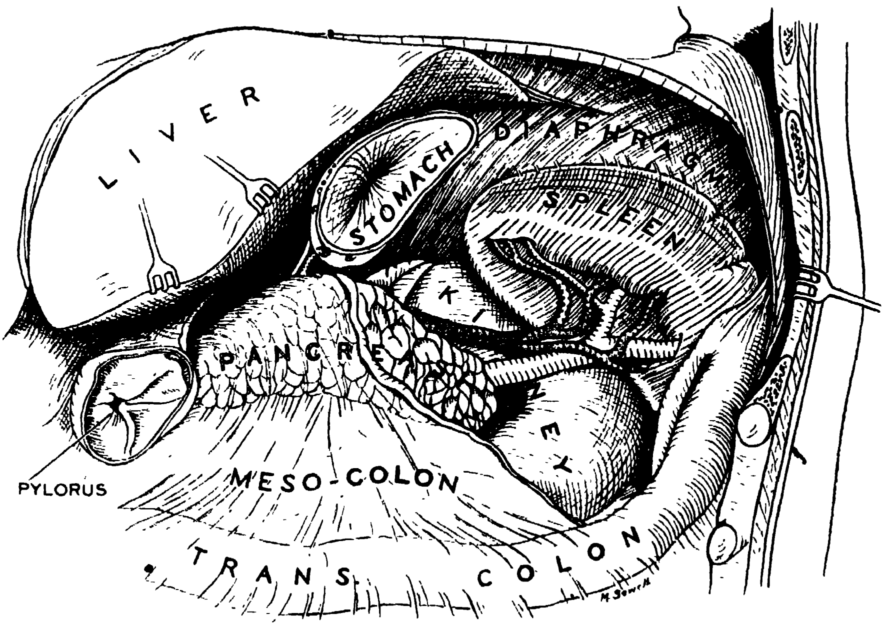


FIG. 261. The stomach bed. (The pancreas is unusually short; the left adrenal gland, the left gastric artery and the branch of the posterior gastric nerve to the coeliac plexus are not labelled.)

and that the junction of 1st and 2nd parts of the duodenum are in contact with the inferior surface of the right lobe beyond the neck of the gall bladder. Obviously the intervening space between these two points must be occupied by the body of the stomach, the pyloric antrum and canal, the pylorus, and the 1st part of the duodenum. You have seen that the 1st part of the duodenum lies beneath the gall bladder; but the duodenum is not nearly as wide as the gall bladder is long; so, it cannot conceal the entire bladder and adrenal, but is separated from these two glands by the peritoneum of the hepato-renal pouch (*fig. 229*). The upper ends of these two glands usually extend above the hepato-renal ligament (i.e., lower layer of the coronary lig.) and, so, come into direct contact with the bare area of the liver. The portion of the left lobe of the liver that fits into the lesser curvature of the stomach is called the *tuber omentale*. It abuts against the lesser omentum which intervenes between it and the tuber omentale of the pancreas.

Note in Review that: (1) One-half of the lesser omentum is attached to the fissure for the lig. venosum; the other half to the porta hepatis. (2) Obliterated fetal veins occupy the fissures for the lig. teres and lig. venosum. The latter can process of the caudate lobe is the narrow stalk between the i. v. cava and the portal vein; it joins the caudate lobe to the under surface of the right lobe proper

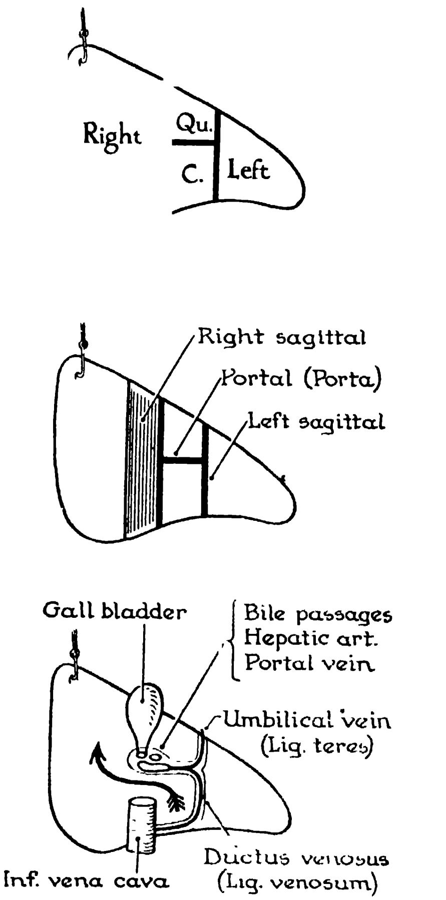


FIG. 262. Diagrams of the liver, hooked upwards to show (a) the H-shaped fissure on the inferior and posterior surfaces, (b) the subdivisions of this fissure, and (c) their contents.

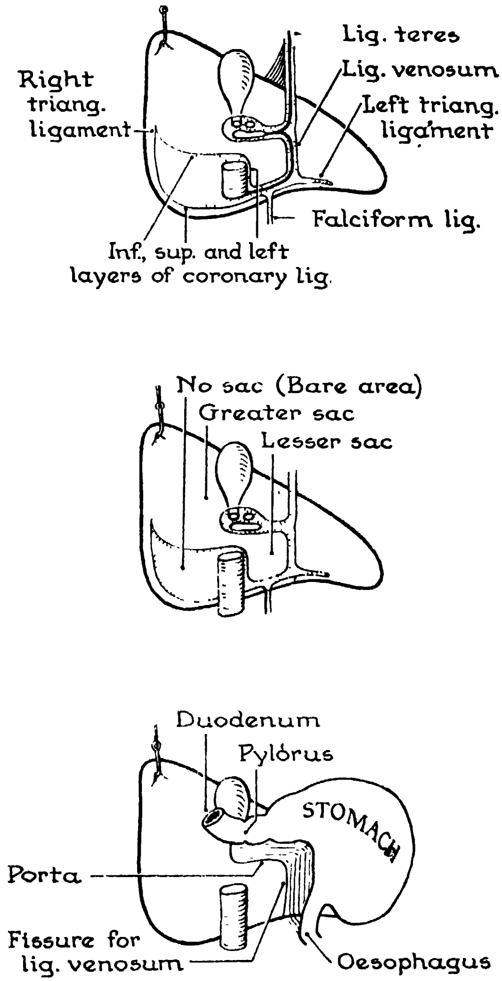


FIG. 263. Diagrams of the liver, hooked upwards to show (d) the peritoneal attachments of its inferior and posterior surfaces, (e) its relationship to the greater and lesser sacs, and (f) the attachments of the lesser omentum.

be traced above the caudate lobe to the i. v. cava. (3) Of the 3 layers of the coronary ligament, the upper and left layers are reflected on to the diaphragm, while the lower (hepato-renal lig.) is reflected onto the kidney and adrenal (and i. v. cava). (4) The tail or caudate and forms the upper boundary of the mouth of the lesser sac. (5) If you care to follow the line of reflexion of the peritoneum from the liver, you will find it to be a continuous line. If there were no bare area—i.e., if the layers of the

coronary ligament were approximated to form an extensive right triangular ligament—much of the complexity associated with the peritoneum would disappear. (6) There are, indeed, 3 bare areas: (a) bounded by the coronary ligament, (b) the fossa for the gall bladder, and (c) where the two sheets of the falciform ligament diverge posteriorly on the upper surface of the liver.

Surface Anatomy of the Liver (*fig. 216*). FROM THE FRONT. (A) *The base* or right lateral limit extends from near the right iliac crest (above or below) in the midlateral line across ribs (11), 10, 9, and 8 up to rib 7. (B) *The upper limit*, of course, is the same as the upper limit of the diaphragm: it crosses the xiphisternal joint in the median plane and rises to the 5th rib in the right midclavicular line; *the apex* or leftmost part fails by an inch to reach the left midclavicular line and lies in the 5th intercostal space 1″ infero-medial to the left nipple. (C) *The sharp inferior border*, of course, connects in wavy fashion the lower limit of the base to the apex. It overlies the pylorus and, therefore, crosses the transpyloric plane about an inch to the right of the median plane.

The position of the *gall bladder* varies with that of the liver. Its fundus typically lies at the lateral border of the Rectus Abdominis somewhat below the costal margin.

FROM BEHIND. For nipples substitute inferior angles of the scapulae (i.e., 7th intercostal spaces in the scapular lines) and for xiphisternal joint substitute the spine of Th. vertebra 8 (i.e., body of 9th Th. vertebra). The lower border follows the 11th or 12th rib (*fig. 286*).

THE MESENTERIC VESSELS

The Superior Mesenteric Artery supplies the small and large intestines from the 2nd part of the duodenum to the left colic flexure. For embryological reasons already given (*fig. 246*), this artery crosses in front of the 3rd part of the duodenum; and there you can pick it up as it enters the root of the mesentery. For embryological reasons to be given (*fig. 272*), it passes between the head and body of the pancreas; and later you can follow it upwards between them to its origin from the aorta close below the origin of the celiac artery. With the body

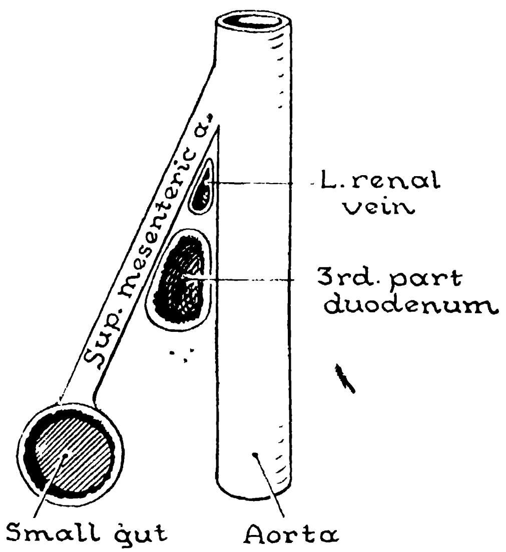


FIG. 264. Compression of the left renal vein and the duodenum.

of the pancreas you should associate the transverse mesocolon, which is attached to the pancreas anteriorly, and the splenic vein, which is embedded in the pancreas posteriorly. These associated structures are the 3 anterior relations of the s. mesenteric artery.

Clamped between the origin of the artery and the aorta, like a nut in nutcrackers, is the left renal vein (as you will see later), and lower is the 3rd part of the duodenum (*fig. 264*). Pressure, exerted through the weight of the in-

testine, would retard the flow of renal blood to the right and of duodenal contents to the left.

Having found the superior mesenteric a. on the duodenum (*fig. 256*), follow it caudally, in the root of the mesentery and applied to the inferior vena cava, to a point beyond the origin of its ileo-colic branch; and thereafter follow it into the mesentery, between whose layers it curves to the right until it reaches the ileum 6 inches from the ileo-colic junction. There it ends by forming an arch with one of its own branches - the ileal branch of the ileo-colic artery.

Branches: (a) To the small intestine: inferior pancreatico-duodenal, jejunal and ileal.

(b) To the large intestine: ileo-colic, right colic, middle colic

THE INFERIOR PANCREATICO-DUODENAL A. arises at the lower part of the head of the pancreas. It divides into an anterior and a posterior branch which, with corresponding branches of the superior pancreatico-duodenal a., form two arches, one in front of the right margin of the head of the pancreas and the other behind it. Each arch gives branches to the head of the pancreas and sends a row of straight terminal vessels, the *vasa recta,* to the 2nd part of the duodenum. Between the two rows of vasa the common bile duct descends. These two arches link the superior mesenteric a. to the celiac a. (*fig. 278*).

JEJUNAL AND ILEAL ARTERIES. 12 or more branches fan out from the left side of the artery into the mesentery where they unite to form loops or arches from which straight terminal branches, *vasa recta,* tend in the main to pass alternately to opposite sides of the jejunum and ileum. Roughly, it may be said that the vasa recta for the 1st quarter of this part of the small gut spring from single arches, those from the 2nd quarter from a double tier of arches, those from the 3rd quarter from a triple tier, and those from the 4th quarter from a quadruple tier. The vasa recta do not themselves anastomose but pass to the submucous plexus where they ramify (*fig. 221*) and the ramifications anastomose freely, i.e., they are end-arteries.

THE 3 COLIC BRANCHES of the s. mesenteric a. arise from its right border. Each runs a strictly subperitoneal course, bifurcates, and joins the artery on each side of it to form loops or arches at a very variable distance (0.5–8 cm.) from the gut wall. The colic branches of the inferior mesenteric a. run similar subperitoneal courses to the left and bifurcate similarly to form loops, and the result is a series of anastomosing links called "the *marginal artery* of Drummond", which extends from the beginning of the ascending colon to the end of the pelvic colon (*fig. 265*) Take care not to damage it. The terminal branches to the colon proceed from "the marginal artery" as described on page 262.

The Ileo-colic Artery descends subperitoneally towards the ileo-cecal region As will be seen later, it crosses first the i. v. cava and then the ureter, genito-femoral nerve, and testicular vessels which lie on the psoas fascia, and divides into an ascending and a descending branch. The descending (ileo-cecal) branch divides into—anterior cecal, posterior cecal, appendicular, and ileal branches. Of these, the *anterior cecal branch* passes in the superior ileo-cecal fold of peritoneum to the front of the cecum and ramifies there. The *posterior cecal branch* ramifies on the back of the cecum. The *ileal branch* anastomoses in in the mesentery with the end of the superior mesenteric a. to form a single, or sometimes double, tier of arches from

which vasa recta proceed to the last 6 inches of the ileum (*fig. 266*). The *appendicular branch* descends behind the end of the ileum and runs in the free edge of the mesentery of the appendix. In 30% of 60 specimens the appendix is supplied by 2 arteries: one from the anterior cecal a. and one from the posterior cecal a., or both from the posterior cecal

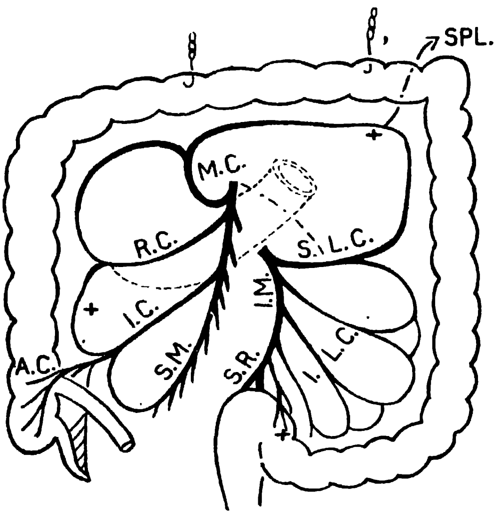


FIG. 265 The superior and inferior mesenteric arteries. (+ denotes three weak points in the marginal anastomosis: between ileo-colic and right colic, between middle colic and superior left colic, between inferior left colic and superior rectal. See p. 262.)

a., or both from the anterior cecal a. (Shah and Shah).

The Right Colic A. crosses the same structures as the ileo-colic a. (except when it arises higher than usual and crosses the duodenum) and divides into a descending and an ascending branch: the latter crosses the lower pole of the right kidney.

The Middle Colic A. arises at the lower border of the pancreas. It curves downwards in the right half of the transverse mesocolon and divides into a right and a left branch. It is in danger of being cut when the right gastro-epiploic artery is being cleaned, as only two layers of peritoneum separate the two vessels.

When the greater omentum and the transverse colon are thrown upwards, the artery then curves upwards in the right half of the transverse mesocolon.

The Inferior Mesenteric Artery supplies the large gut from the left end of the transverse colon to the lower end of the rectum. It arises from the front of the aorta $1\frac{1}{2}$ inches above its bifurcation, therefore $\frac{3}{4}$ inch above the umbilicus, and

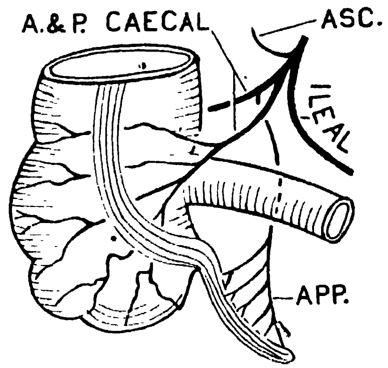


FIG. 266. The branches of the ileo-colic artery.

therefore in front of the 3rd lumbar vertebra, where the lower border of the duodenum overlaps it. It descends subperitoneally on the aorta and the psoas fascia, crosses the left common iliac artery, and enters the pelvis as the superior rectal (sup. hemorrhoidal) a.

Branches:

(a) upper left colic,

(b) lower left colic (sigmoid).

The Upper Left Colic Artery arises 1–2 inches along the stem of the i. mesenteric a. and passes sub-peritoneally to the left across the testicular vessels, ureter, and inferior mesenteric vein and divides into an ascending and a descending branch. Of these, the ascending branch crosses the lower pole of the left

kidney, just as the ascending branch of the right colic a. crosses the lower pole of the right kidney.

The Lower left colic (*sigmoid*) *Arteries* are generally 2-4 in number (*fig. 267*). The first commonly arises from the upper left colic artery; the lowest from the upper end of the superior rectal (sup. haemorrhoidal) artery. The upper branches cross the structures in front of the Psoas, (viz., inf. mesenteric vein, ureter, genito-femoral nerve, and testicular vessels). The lower branches cross the common or external iliac vessels and enter the horizontal part of the pelvic meso-colon where they form two or three tiers of arches.

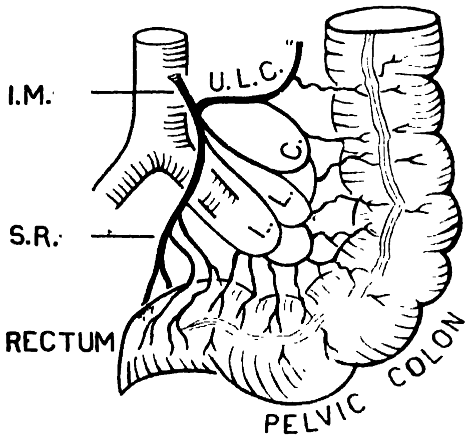


FIG. 267. The branches of the inferior-mesenteric artery. (After Steward).

The Marginal Artery (of Drummond). The end of the s. mesenteric a. and adjacent branches of the ileo-colic, right colic, middle colic, upper left colic, and lower left colic (sigmoid) arteries form a series of anastomosing loops which extend from the end of the ileum to the end of the pelvic colon. The loops are for the most part single, though at places—notably at the right colic flexure and at the diagonally opposite pelvic colon—they commonly form double or even triple tiers. The result is a continuous marginal artery situated from 0.5 to 8.0 cm. from the wall of the large gut. It is closest along the descending and pelvic colons.

Long and short terminal branches proceed from "the marginal artery" to the colon (*fig. 268*). The long branches bifurcate near the mesenteric border into anterior and posterior branches which run a subserous course in the haustra for one-third of the circumference of the gut, that is to the next taenia, and then pass deep to the taenia, pierce the circular muscle coat, and enter the submucous plexus. The anastomoses they effect across the anti-mesenteric border are meagre. The short branches, which are 4-5 times as numerous as the long branches, spring both from the long branches and from the marginal artery directly. They pass to the mesenteric border and to the mesenteric two-thirds of the circumference. Like the long branches they pass to the submucous plexus after a short tortuous subserous course The muscle coats are mainly supplied by recurrent branches from the submucous plexus.

VARIATIONS. (a) In about 5 per cent of 100 specimens the marginal artery is discontinuous, due to the ileo-colic a. failing to anastomose with the right colic. (b) The right colic a. very commonly takes origin either from the middle colic or the ileo-colic artery. (c) The middle colic a. commonly has an accessory left branch. (d) The left colic a. supplies the left end of the transverse colon in about 67 per cent of cases, and in 33 per cent it fails to reach the left colic flexure. (e) The middle colic and left colic aa. probably always anastomose, although the portion of the marginal artery so-formed is long and usually single. (f) A large branch (the arc of Riolan) not

rarely connects the stem of the s. mesenteric a. with the left colic a. on the posterior abdominal wall. (g) Occasionally a branch connects the left colic a. with the splenic a. (h) The marginal artery does not link up the lower left colic a. with the superior rectal a.—except occasionally and feebly- so, if the superior rectal a. is obstructed beyond the origin of the lowest of the left colic aa., there is little chance of an effective collateral circulation being established (*fig. 265*).

when these are present, and ends either in the splenic vein, which is embedded in the posterior surface of the pancreas, or curving medially it crosses in front of the stem of the s. mesenteric artery to the angle between the s. mesenteric and splenic veins. The branches of the lower and upper left colic arteries necessarily cross it, optionally in front or behind; the testicular artery and the genito-femoral nerve also cross it, but without option —they, of course, cross behind.

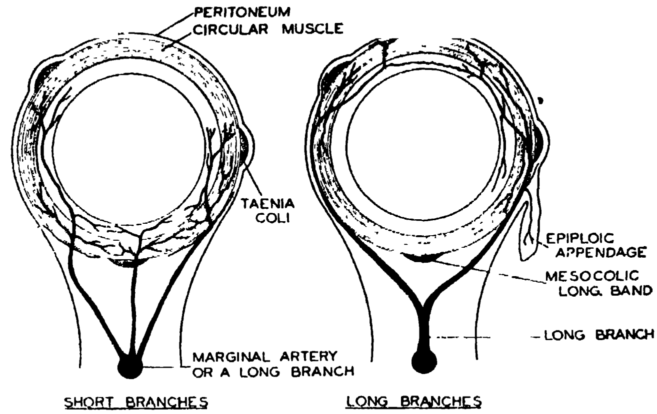


FIG. 268. The blood supply of the colon. (After Steward)

The Superior Mesenteric Vein lies on the right side of its artery. This you might expect from the facts that the artery arises from the aorta which occupies the median plane, and that the vein ends in the portal vein which, as you have seen, ascends in front of the i. v. cava—a structure situated to the right of the median plane.

The Inferior Mesenteric Vein is the continuation of the superior rectal vein (sup. haemorrhoidal vein). It begins in front of the left common iliac artery and ascends subperitoneally on the psoas fascia between its artery, which lies medially, and the ureter which lies laterally. It occupies the free edges of the para- and superior duodenal fossae,

The Left Testicular Vein enters the abdomen through the deep inguinal ring and ends in the left renal vein; so, it begins lateral to the inferior mesenteric vein and it remains lateral; should it happen to cross, it would, of course, do so posteriorly. In short, the inferior mesenteric vein is part of the portal system, but the testicular vein is not; so, by following these veins to their terminations (i.e., to their recipient veins) they can infallibly be distinguished.

Structure of the Intestines from Jejunum to Pelvic Colon. When this portion of the gut is opened either entirely or in 3″ to 4″ stretches, folds of mucous membrane, the *plicae circulares*, are seen running transversely for variable dis-

tances around the gut wall and commonly branching. Unlike the folds or rugae in the stomach, these are permanent; they contain a skeleton of areolar tissue derived from the submucous coat; and they greatly increase the absorptive surface of the gut. They begin in the duodenum, 1″ to 2″ from the pylorus, and end beyond the middle of the ileum. In the duodenum and upper part of the jejunum they are high (about 6 mm.) and closely set; lower down they gradually become smaller and more widely separated. Towards the middle of the ileum collections of lymphoid tissue, *solitary lymph nodules*, 2–3 mm. in diameter, appear and are present throughout the remainder of the small and large guts. On holding the otherwise translucent gut to the light, they appear as dark patches. Also in the ileum, at the antimesenteric border, are 20 or more *aggregated lymph nodules* (Peyer's patches); they are oblong, ½″ wide by 1″ or more long, the long axis being in the long axis of the gut. Lymphoid tissue being a tissue of youth, these nodules are not commonly seen in dissecting-room subjects. Finger-like projections, *villi*, (.5 to 1.5 mm. long) cover the mucous surface from pylorus to ileo-colic valve. They are best seen under water with a lens. They, too, greatly increase the absorptive surface of the gut.

The Ileo-colic (ileo-caecal) Valve. Here the circular muscle of the small gut, covered with mucous membrane, pouts into the large gut. The orifice or mouth is a transverse slit; its upper lip overhangs the lower and, so, directs issuing contents downwards into the caecum. From each angle (anterior and posterior) of the orifice a fold, the *frenulum*, extends transversely. In certain hardened and contracted specimens the orifice is circular.

The Appendix opens into the caecum ½″ to 1½″ below the ileo-colic valve. Its mouth may be guarded by a semilunar fold of mucous membrane. Its mucous coat is packed with lymph nodules, having germinal centres like the (palatine) tonsil. Its lumen is narrow and attempts to inject it (e.g., with melted paraffin wax) commonly fail, because it is commonly partly obliterated and fibrous.

The sacculations or *haustra* of the caecum and colon are permanent, the taeniae coli acting as elastic bands; but on nicking the taeniae, the gut may be lengthened and the sacculations disappear.

The mucous and sub-mucous coats of the gut are readily peeled off the circular muscle coat, and the vessels entering the submucosa are then seen.

DUODENUM AND PANCREAS

The word *Duodenum* is a Latin corruption of the Greek word dodekadaktulos, meaning twelve fingers, (cf. the 12 islands in the Levant called the Dodecanese Islands). About 300 B.C. Herophilus of Alexandria gave the name do-deka-daktulos to the first part of the intestine before it is thrown into folds. It was so-called from its being as long as twelve fingers are broad in those animals in which it was first described (Finlayson). In man the duodenum is the part of the small intestine that has lost its dorsal mesentery. Ten inches long it is moulded around the head of the pancreas in horse-shoe fashion and is divided into four parts:

1st or superior—two inches long.
2nd or descending—three inches long.
3rd or horizontal—four inches long.
4th ascending—one inch long.

Surface Anatomy: Vertebral Levels. The duodenum begins at the pylorus in the transpyloric plane an inch to the right of the median plane, and ends at the duo-

deno-jejunal junction slightly below the transpyloric plane an inch to the left of the median plane. The ends of the horseshoe are, therefore, two inches apart. Where the 3rd part of the duodenum crosses the median plane, it overlaps the origin of the inferior mesenteric artery. Though this is of little importance in itself, it is a noteworthy index to the surface anatomy and vertebral level of the 3rd part of the duodenum (*fig. 269*).

Thus:—The umbilicus lies at the level of the disc between the 3rd and 4th lumbar vertebrae, and is midway between the origin of the inferior mesenteric artery and the aortic bifurcation. The artery arises ¾ of an inch above the umbilicus and therefore in front of vertebra L. 3; the bifurcation takes place ¾ of an inch below the umbilicus and therefore in front of the vertebra L. 4. With this information and knowing the vertebral level of the transpyloric plane, it becomes a simple matter to map out the duodenum on the surface of the body and to relate it to the vertebrae.

The Pancreas (Gk. Pan = all; kreas = flesh) resembles the letter J, or better a retort, set obliquely. The bowl of the retort, known as the *head* of the pancreas, lies within the concavity of the duodenum, whilst the stem of the retort, divided indefinitely into *neck*, *body*, and *tail*, slants obliquely across the abdomen. The tip of the tail abuts against the spleen and lies above the level of the head. The pancreas has two processes: (a) the *uncinate process*, which projects from the lower part of the head medially behind the superior mesenteric vessels, and (b) the *tuber omentale*, which pro-

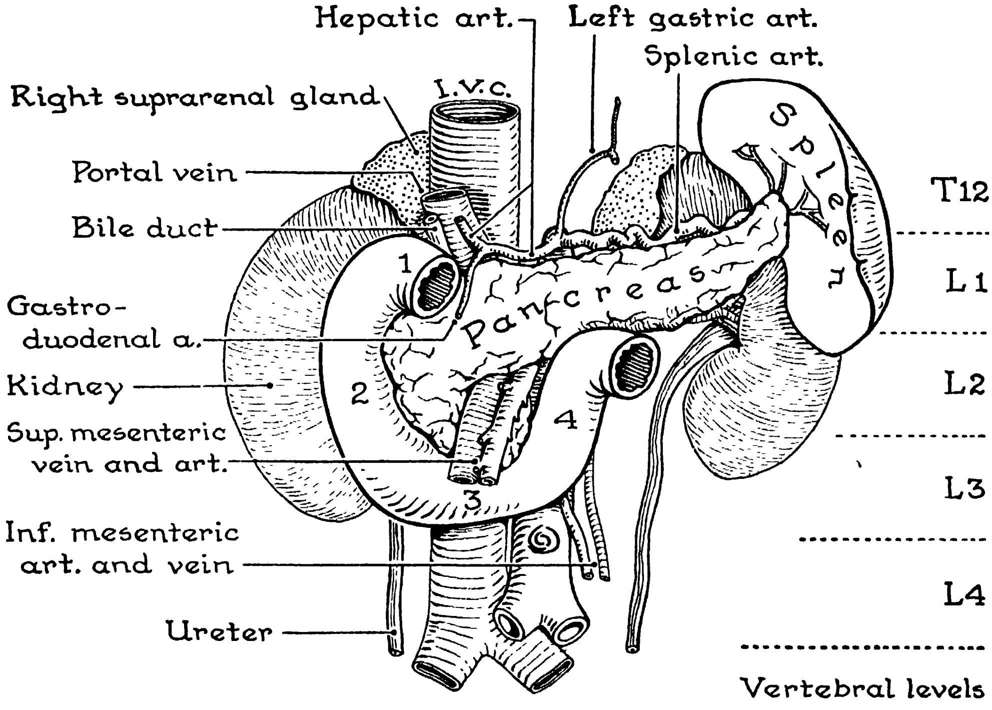


FIG. 269. Abdominal viscera and vessels

jects upwards from the body and fits into the lesser curvature of the stomach. There it abuts against the lesser omentum which separates it from the downwardly projecting tuber omentale of the left lobe of the liver.

The celiac artery, with the crura of the diaphragm astride it, lies at the upper border of the pancreas and sends its hepatic branch to the right along the upper border of the neck and head of the pancreas, and the splenic branch to the left along the upper border of the body and tail of the pancreas.

Surface Anatomy: Vertebral Levels. With these facts, and recalling that the diaphragm descends in the median plane to the disc between the last thoracic and first abdominal (or lumbar) vertebra, it becomes a simple matter to map out the pancreas on the surface of the body and to relate it to the vertebrae. Thus:—The head lying within the concavity of the duodenum lies in front of vertebra L. 2; the body rises to the level of the celiac artery and, therefore, is in front of vertebra L. 1; whilst the upwardly sloping tail is at the level of vertebra Th. 12.

Development. Before proceeding further with a description of the relations of the duodenum and pancreas, the following essential embryological considerations should be recalled:—

1. When at the fourth month of fetal life the cecum and adjacent parts of the intestine are withdrawn from the extra-embryonic celom (in the umbilical cord), the intestines undergo rotation, counter clock-wise, on the axis of the superior mesenteric artery, in consequence of which the stem of the artery comes to lie in front of the 3rd part of the duodenum and behind the transverse colon (*fig.* 246). Thereafter, the *duodenum* is thrust by the transverse colon against the structures lying on the posterior abdominal wall, and it loses its dorsal mesentery; that is, the right layer of its mesentery adheres to the structures on the posterior wall of the abdomen. The *pancreas*, which lies between the two layers of the dorsal mesentery, likewise loses the layer of peritoneum which formerly clothed its right surface—now its posterior surface. The *transverse colon* in turn loses part of its mesocolon where it crosses the second part of the duodenum and the head of the pancreas, but retains it where it lies in front of the body of the pancreas (*figs.* 25 276).

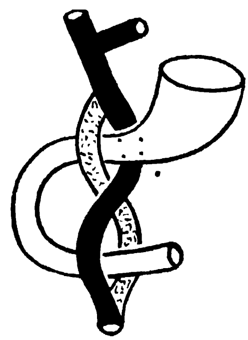


FIG. 270. Showing how the portal vein develops from a figure-of-8 anastomosis around the duodenum.

2. The right and left vitelline veins, returning blood from the yolk sac, are so united to each other below the liver as to suggest that the upper and lower limbs of the duodenum are held in venous manacles (*fig.* 270). The veins twine about the duodenum in figure-of-8 fashion. The splenic vein comes to open into the intermediate part of this figure-of-8. The portions of the 8 anterior to the first part of the duodenum and posterior to the third part disappear with the result that the superior mesenteric, splenic and portal veins of adult anatomy take form.

3. The ducts of the liver and pancreas arise as two outpouchings of the endoderm of the duodenal wall. The gland-

ular tissue of the liver and pancreas develops from the ends of the ducts: the remainder is of mesodermal origin. One endodermal bud grows from the posterior border of the duodenum into the dorsal mesoduodenum. It is the rudiment of the accessory pancreatic duct (of Santorini). Around it the neck, body, and tail of the pancreas develop. From the anterior border of the duodenum, and at a lower level, another endodermal bud grows into the ventral mesoduodenum

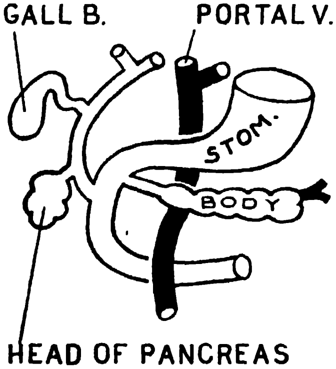


FIG. 271. The rudiments of the liver and pancreas arise as outpouchings of the duodenum into the ventral and dorsal mesogastria.

(or mesogastrium). It is the rudiment of the bile ducts and of the liver and also of the main pancreatic duct around which the head of the pancreas develops (*fig. 271*).

4. The 2nd part of the duodenum undergoes partial rotation on its own long axis, due to the fact that different parts of its wall grow unequally. As a consequence, the opening of its upper or accessory duct, which was formerly posterior, is now carried to the front; and the duct which was originally anterior and lower is carried posteriorly to the concave border (*fig. 272*). This explains why the (common) bile duct passes upwards behind the accessory pancreatic duct and first part of the duodenum.

For descriptive purposes, the head of the pancreas may be regarded as swinging round behind the junction of the splenic, superior mesenteric, and portal veins, thereby causing them to occupy a position between it and neck of the pancreas. The pancreas seems to close on these veins much as a book might close on a bookmark.

5. The tail of the pancreas, growing between the layers of the dorsal meso-

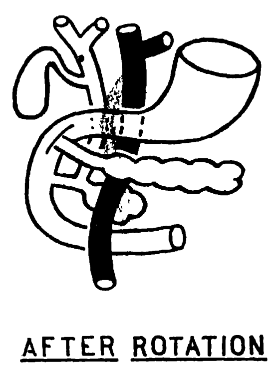


FIG. 272. The two rudiments of the pancreas close on the portal vein (or s. mesenteric vessels) like a book on a book mark.

duodenum, ultimately abuts against the spleen which develops from the left layer of the dorsal mesogastrium (*figs. 249, 250*).

6. A communication is established between the two ducts of the pancreas. Thereafter, the lower duct conducts the main volume of pancreatic juice into the duodenum. It is true that in about 13.0 per cent of persons the two ducts fail to unite; that in 15 to 25 per cent the orifice of the upper duct becomes occluded, and, therefore, that in 28 per cent or more persons it would not be possible for fluid in the lower duct to pass into the duodenum via the upper duct. Though the lower duct rarely becomes occluded, the

upper duct in say 8 per cent is larger than the lower (*fig. 279*). (Baldwin.)

The duodenum was defined above as the part of the small gut that had lost its mesentery. This is not true of the first inch of the duodenum, for it has two

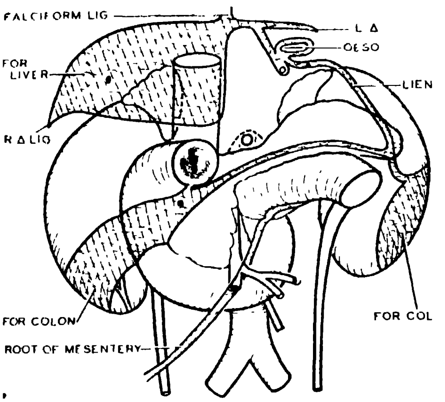


FIG. 273. The retroperitoneal viscera which lie on the posterior abdominal wall (rough areas are devoid of peritoneum).

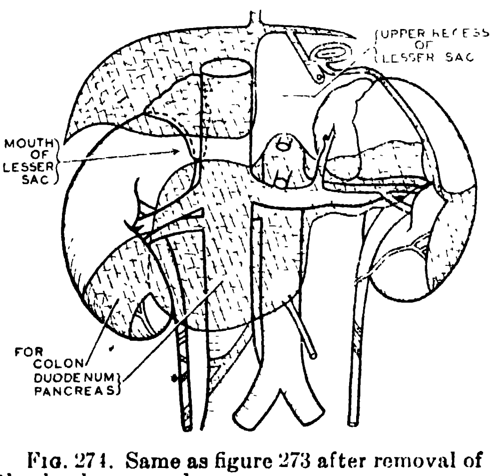


FIG. 274. Same as figure 273 after removal of the duodenum and pancreas.

mesenteries—the lesser omentum, which is attached to its upper border, and the greater omentum, which is attached to its lower border. They allow the first inch to move freely with the stomach.

The Anterior Relations of the Duodenum and Pancreas. You have seen that the gall bladder rests on the first part of the duodenum and on the transverse colon (*fig. 228*). The 1st part of the duodenum, however, is longer than the gall bladder is wide; so, it is in contact with the liver on each side of the gall bladder. Its antero-superior relations are: quadrate lobe, neck of gall bladder, and right lobe. The transverse colon is the direct anterior relation of the 2nd part of the duodenum. The superior mesenteric vein and artery cross anterior to the 3rd part of the duodenum in the root of the mesentery; and clinically they

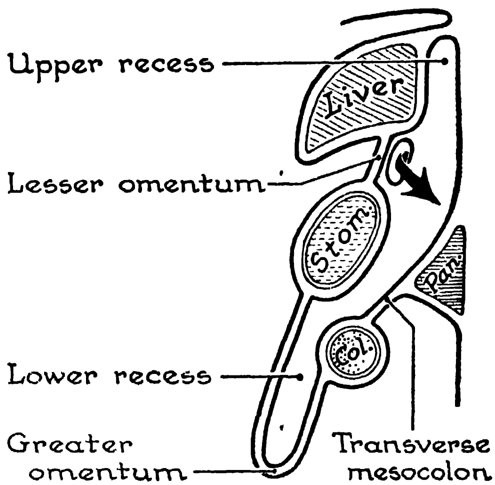


FIG. 275. Diagram of the stomach, lesser sac, and stomach bed, on sagittal section.

appear at times to constrict the duodenum. Indeed, in the dissecting rooms, the duodenum is commonly found to be dilated before the site of crossing and contracted beyond. Coils of jejunum lie in front of the remainder of the duodenum.

The pancreas has two aspects, an *anterior* and a *posterior*. The transverse colon is attached to the anterior aspect of the head by areolar tissue and is suspended from the anterior aspect of the body and tail (near its lower part) by the transverse mesocolon. When the sur-

rounding hollow viscera are distended, the body of the pancreas becomes triangular on cross section, in which case the line of attachment of the transverse mesocolon becomes the *anterior border*, the area above it the antero-superior surface; and the area below it the antero-inferior surface (*fig. 275*). The antero-superior surface is obviously covered with peritoneum of the lesser sac; the antero-inferior with peritoneum of the greater sac. The tip of the tail extends into the lieno-renal ligament and abuts against the spleen.

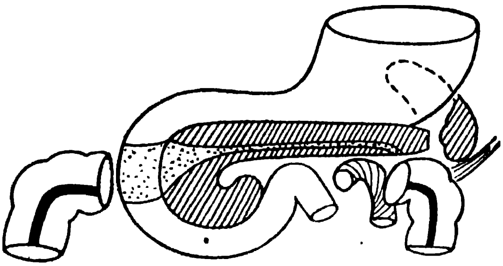


FIG. 276. Relations of the gastro-intestinal apparatus to the pancreas

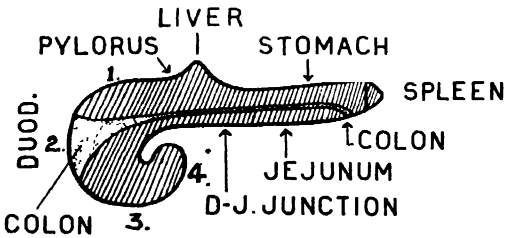


FIG. 277. Key to figure 276.

The pancreas is surrounded by various portions of the gastro-intestinal tract, and these come to overlie it as shown in figures 276, 277. The 1st part of the duodenum, to be more precise, overlaps the front of the head of the pancreas; its 2nd and 3rd parts are overlapped by the head.

The Posterior Relations of the Duodenum and Pancreas (*fig. 274*) are those structures that lie in front of the posterior abdominal wall from the level of the celiac artery above to the inferior mesenteric artery below; and, from the hilum of the right kidney to half way across the anterior surface of the left kidney, where the tail of the pancreas enters the lieno-renal ligament and touches the spleen. These structures belong to the "three paired gland system" and to the great vessels, and will be appreciated more fully when they have been dissected. It is, of course, understood that the duodenum and pancreas do not adhere to

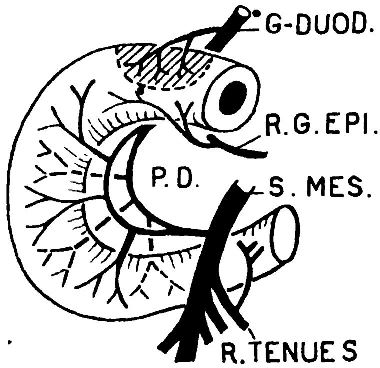


FIG. 278. The blood supply of the duodenum.

these posteriorly lying structures, save in the median plane. They are separated from them by two areolar membranes, the remains of the two peritoneal layers (devoid of their squamous epithelial lining) that originally separated them. Between these two layers there is no structural continuity.

The Blood Supply of the Duodenum and Pancreas (*fig. 278*). The duodenum and the head of the pancreas are situated at the site of union of the celiac and superior mesenteric arterial systems, and are supplied largely by the superior and inferior pancreatico-duodenal arteries. These two arteries anastomose to form an arch in front of the head of the pancreas and another arch behind it. From these two arches the 2nd and 3rd parts of

the duodenum receive an anterior and a posterior row of vasa recta. In this respect the duodenum is unique, for no other part of the gut, either small or large, receives two rows of vasa.

The body and tail of the pancreas are supplied by two constant arteries: (a) the *splenic artery* which runs behind the upper border of the gland, and (b) the *inferior pancreatic artery* (commonly derived from the sup. mesenteric a.) which runs behind the lower border. Other, inconstant arteries supply the gland. (Pierson; Wharton.)

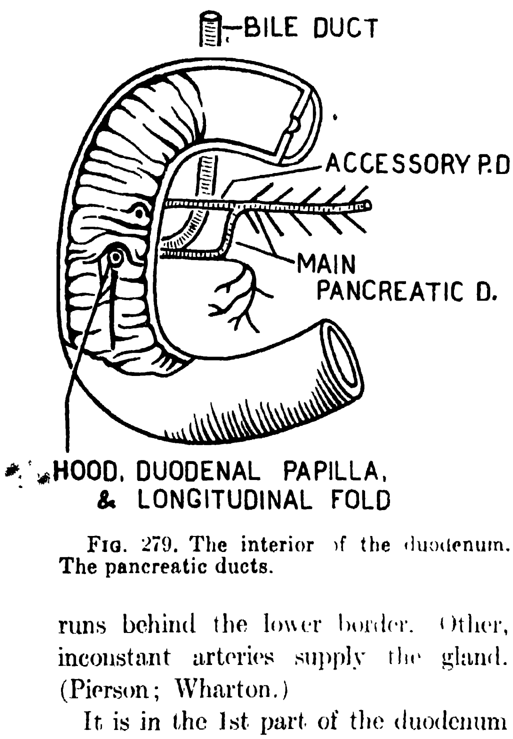


FIG. 279. The interior of the duodenum. The pancreatic ducts.

It is in the 1st part of the duodenum that duodenal ulcers occur. The blood supply is therefore of interest. The upper border, two-thirds of the anterior surface, and one-third of the posterior surface of the first inch-and-a-half of the duodenum are supplied by what is practically an end-artery, the *supraduodenal branch* of the gastro-duodenal a. (sometimes from the common, right, or left hepatic aa.). Another independent twig (or twigs), the *retro-duodenal branch* of the gastro-duodenal a., helps to supply the posterior wall. The right gastroepiploic a. supplies the inferior border; the right gastric a. may supply a twig to the upper border.

The Structure and the Interior of the Duodenum (*fig. 279*). A cast of the duodenum, made by pouring melted paraffin wax into it, shows that: (a) its first one or two inches are smooth; beyond this, *plicae circulares* of mucous membrane are large and numerous; (b) the conjoint bile and main pancreatic duct, which dilates as it traverses the duodenal wall to form the *ampulla* of Vater (5 mm. long), opens on to the *duodenal papilla* of Vater, which is situated on the concave side of the duodenum 3 inches from the pylorus; (c) from the papilla a *plica longitudinalis* descends, and over the papilla a semicircular *hood-like fold* is commonly thrown; (d) the accessory pancreatic duct opens into the duodenum on an *accessory papilla*, $\frac{3}{4}''$ antero-superior to the duodenal papilla. (e) Sometimes the duodenal papilla is situated at the end of a short conical diverticulum of the duodenal wall. Sometimes the bile and main pancreatic ducts open on the papilla independently, one above the other.

The duodenum has a complete tunic of racemose glands, the ***duodenal glands*** of Brunner. In that they lie outside the tunica muscularis mucosae, they resemble the mucous glands of the esophagus and differ from all other glands of the gastro-intestinal tract.

The main duct of the pancreas runs near the posterior surface of the gland and should be dissected from behind. It resembles a herring bone, in that small ducts spring from the main duct which is straight; hence, microscope sections of the gland reveal either large ducts or small ducts, but no ducts of intermediate

size. By this the pancreas may be distinguished from other serous glands, such as the parotid and lacrimal, which have arborising ducts of graded sizes.

In displaying the (common) bile duct you should make use of your embryological knowledge and re-open obliterated portions of the peritoneal cavity (*fig. 280*). (1) First, pull the transverse colon downwards from off the front of the 2nd part of the duodenum and head of the pancreas. When done, note that the posterior aspect of the transverse colon is covered with a smooth areolar membrane and that the bared parts of the duodenum and pancreas are similarly covered. These are the areolar layers of peritoneum from which the squamous cells have been absorbed. In short, you have restored to the right end of the transverse colon its primitive mesocolon. (2) Then raise the duodenum and head of the pancreas, and swing them forwards, as though on a hinge, towards the median plane. Note that their posterior surfaces are covered with a smooth areolar membrane and that the anterior surfaces of the kidney, renal vessels, and i. v. cava, from which they have been raised, are similarly covered. You have restored in part the mesoduodenum. (3) You can now follow the bile duct downwards behind the 1st part of the duodenum and head of the pancreas, and between the two rows of vasa recta duodeni that proceed from the anterior and posterior arches of the pancreatico-duodenal vessels, and so to its junction with the main pancreatic duct 3 inches from the pylorus. Below the mouth of the lesser sac the bile duct is separated from the i. v. cava by two areolar membranes, the posterior row of vasa recta, and commonly in its last half inch by a portion of the head of the pancreas.

Warning. To expose the (common) bile duct from the front is destructive:—the transverse colon must be pulled down, the 1st part of the duodenum cut across, the anterior row of vasa recta and the accessory pancreatic duct cut across, in order that the head of the pancreas may be separated from the second part of the duodenum. Further, the pancreas invades the duodenal wall around the accessory duct; hence, separation involves laceration.

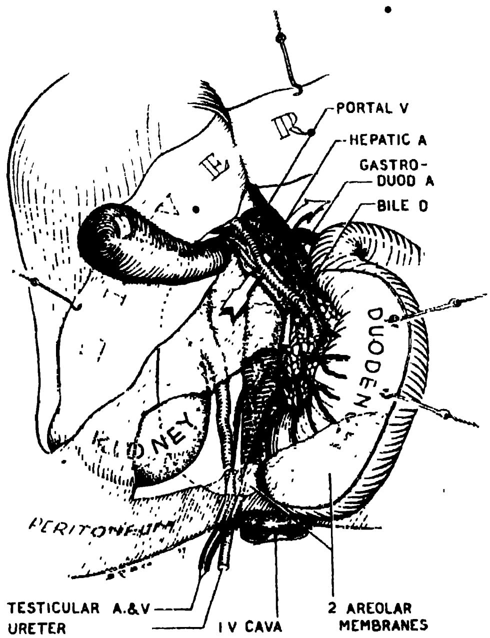


FIG. 280. Display of the bile duct by the embryological approach—see text. (Arrow passes through the mouth of the lesser sac.)

Observation. Trace downwards the 3 *chief structures in the free edge of the lesser omentum* noting their different relationships to the head of the pancreas. Thus: (1) The (*common*) *bile duct* passes behind the head. (2) the *portal vein*, prolonged as the superior mesenteric vein, passes between the head and neck. (3) The *hepatic artery*, prolonged as the gastroduodenal artery, passes between the head and the duodenum, ¾ of an inch from the

pylorus. Note that two of these, the bile duct and the portal vein, are important anterior relations of the i. v. cava. Both are separated from the i. v. c. by two areolar membranes; the bile duct is also separated from it by a row of vasa recta.

The Bile Passages and the Gall Bladder. STRUCTURE. The *intrahepatic ducts* begin as intralobular ductules which

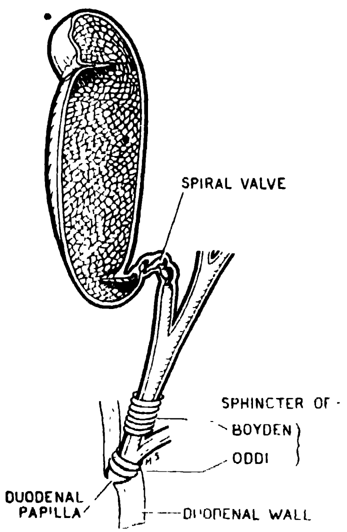


FIG. 281 The mucous membrane of the gall bladder and extra-hepatic bile passages. The two sphincters are shown diagrammatically This bladder happened to have a folded fundus.

are merely clefts between cords of contiguous liver cells. These are continued as interlobular ducts which are lined with cubical cells, and which anastomose freely with adjacent ducts, and accompany the branches of the portal vein and hepatic artery (*fig. 45*). The *extrahepatic ducts* (viz., right and left hepatic, common hepatic, cystic, and bile) are fibrous tubes containing many elastic fibres and lined with columnar epithelium, but without a muscle coat, except at the lower part of the bile duct where there is a sphincter which apparently can support a column of bile (Boyden). Another sphincter (Oddi) guards the common termination of the bile and the pancreatic duct. In the cystic duct there is a spiral fold which probably serves to keep the duct patent (*fig. 281*). The extrahepatic ducts have a thin watery secretion.

The inner surface of the *gall bladder* is covered with small polygonal compartments, opening on to the interior, and resembling the cut surface of a honeycomb. Like villi, these greatly increase the absorptive surface and, indeed, on cross section the walls of the compartments look like villi. The wall of the gall bladder has: a single, inner layer of columnar cells, a tunica propria, a muscle coat of decussating fibres, a subserous coat, and a serous coat (except where the bladder is applied to the liver). Although the gall bladder is an outgrowth of the small intestine, it differs from it in having (a) no goblet cells (but it secretes a thick mucinous material), (b) no tunica muscularis mucosae, and (c) no separate inner and outer muscle coats. At the neck of the bladder there are some tubulo-alveolar glands.

FUNCTION. The function of the gall bladder is to concentrate (hence the large honeycomb absorptive surface) and store the bile brought to it from the liver via the cystic duct between meals and to discharge it into the intestine via the cystic duct during meals. Thus, dilute bile flows up the duct and concentrated bile flows down again.

THE VESSELS AND NERVES to the gall bladder. The *cystic artery*, a branch of the right hepatic, ramifies both on the free surface of the bladder and on the attached. Occasionally there is an accessory cystic artery derived from the right, the left, or the common hepatic artery. The *cystic vein* empties into the right portal vein. The *lymph vessels* pass to the cystic gland at the neck of the

bladder and thence downwards along the biliary chain. The *nerves* are derived from the gastric nerves (vagi) and from Th. 7, 8, 9 via the coeliac ganglion.

Development and Variations. The bile duct developed as an outgrowth from the duodenum (*fig. 227*). It branched and rebranched more or less dichotomously. One of the main branches, the *cystic duct*, instead of branching gave rise to a blind vesicle, the *gall bladder*. Occasionally the gall bladder, "forgetful" of its modified function, branches too; this explains fig. 282-H.

Precocious branching of the bile passages is common, and when the branch is in surgical danger, the fact is of importance. Thus, the cystic duct may end much lower than usual (*fig. 282*) or much higher, sometimes joining the r. hepatic duct (B), and it may swerve across the common hepatic duct (C). When there are two right hepatic ducts, the lower is called an *accessory hepatic duct*. Accessory hepatic ducts may end as depicted (D, E, F, G, H).

The gall bladder is rarely absent (unless, like an offending appendix, it has been removed). It is rarely buried in the liver, but occasionally it is suspended from the liver by an acquired mesentery. It is commonly attached to the transverse colon or to the duodenum by a peritoneal fold. Occasionally it has a sacculation at its neck (Hartman's pouch), and occasionally the fundus is congenitally folded upon itself within its serous or peritoneal coat (*fig. 281*), or the folding may include the serous coat. Although bilobed gall bladders are very common in domestic animals, in man they are rare; [17 cases of double bladder, however, each with a separate cystic duct, have been reported (Boyden)].

Structure of the Liver, Pancreas, and Spleen. The Liver. On examining a sagittal section of the liver passing through the porta, the following facts may be determined. The serous (peritoneal) covering and the underlying

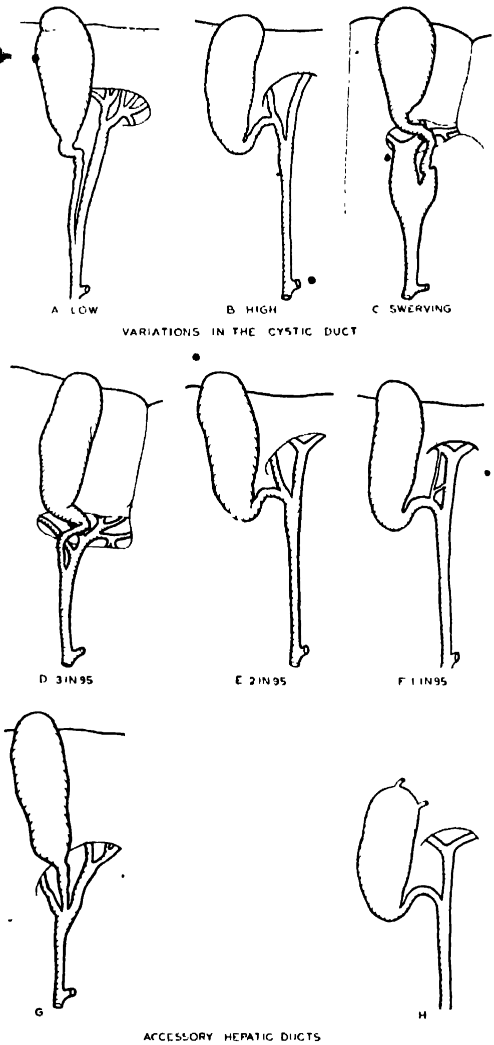


Fig. 282. Precocious bile ducts. A, B and C = variations in the length and course of the cystic duct. D, E, F, G and H = accessory right hepatic ducts. (Of 95 gall bladders and bile passages injected in situ with melted wax and then dissected, 6 had accessory hepatic ducts in positions of surgical danger. Of these, 3 joined the common hepatic duct near the cystic duct (D), 2 joined the cystic duct (E), and 1 was an anastomosing duct (F). Accessory ducts may join the bile duct (G), and also the gall-bladder (H). All except H were sketched from specimens.)

fibrous capsule are adherent to each other, delicate, and easily torn from the liver substance. At the porta the *capsule* (Glisson's capsule) is carried into the liver as a sleeve that envelops the portal vein, hepatic artery, and hepatic ducts (also lymph vessels and nerves), and it branches whenever they branch. The cut surface is smooth and is made up of innumerable, small, mottled areas, each representing a lobule. Scattered here and there are sections across branches of the sleeve-like capsule, in which are seen an hepatic duct (commonly stained green with bile), a small branch of the hepatic a. (commonly injected), and a branch of the portal vein (commonly collapsed)—all lying in an areolar bed. Elsewhere there are small round spaces, i.e., sections of the *hepatic veins* and their tributaries; these, having little, if any, areolar tissue around them, adhere to the liver substance and remain patent. The portal vein is an afferent vein—it has branches; the hepatic veins are efferent veins—they have tributaries and they converge on the i. v. cava (p. 53). A broken or torn surface of the liver is granular like a torn surface of the labyrinth of the kidney.

THE PANCREAS is made up of lobules loosely held together; it has no capsule. A cross-section hardly differs in appearance from a surface view, except that in it the white-walled duct, with tributaries entering it in herring-bone fashion, is seen (p. 54).

THE SPLEEN on section. Little can be distinguished. If hardened, it is stuffed with blood, granular, and red; the serous covering adheres to the thin fibro-musculo-elastic capsule; from the capsule, trabeculae pass into the substance of the spleen. If not hardened, the pulp may be washed and gently squeezed away under the tap, leaving only the capsule, framework, and vessels. In a fresh specimen, small white spots, the *Malpighian corpuscles*, are seen scattered over the cut surface (p. 54).

CHAPTER 10

THE THREE PAIRED GLANDS

Having disposed of the gastro-intestinal canal and its three associated unpaired glands, you are in a position to consider the remaining abdominal organs, which are the adrenal, the renal, and the sex glands. These three paired glands together with their ducts, vessels, and nerves may be referred to collectively as the three paired gland apparatus. Of the three paired glands, the *adrenals* have an internal secretion and are ductless; the *kidneys* have an external secretion called the urine, which is conducted to the urinary bladder by ducts called the ureters; the *sex glands* have an internal secretion and an external. The external secretion of the testes, called *spermatazoa*, is conducted to the urethra by the ducts of the testes, called the vasa deferentia. The external secretion of the ovaries, called *ova*, is conducted to the uterus by ducts, called the uterine or Fallopian tubes.

Migrations. All three glands developed in the subperitoneal tissue; and subperitoneal they remain, save where parts of the gastro-intestinal apparatus "fall" in front of them and, owing to obliteration of the peritoneal cavity in between, adhere to them (*figs. 248, 274*). The adrenal glands developed in situ. That the testes (and ovaries) descend is common knowledge; that the kidneys ascend is equally true, though it may be less generally known. As the testis and kidney migrate, the one down and the other up, their paths cross and in crossing one obviously must be in front of the other (*fig. 283*). If you are not familiar with the developmental history of these glands, you may have to tax your memory to recall which crosses in front and which behind, though a quite permissible mnemonic presents itself in the fact that the testes ultimately lie in the ventral region of the body; the kidneys in the dorsal. This happens to be the relation of the one gland to the other where they cross.

The ascending kidney dragged its duct after it and picked up new vessels during its ascent. The descending testis (or ovary) dragged after it not only its duct but also its artery, vein, lymph vessels, and nerves. And it dragged them in front of the path of the kidney. Definitively, the testicular (or ovarian) vessels and nerves cross the ureter in the abdomen; the vas deferens (or uterine tube) crosses it in the pelvis.

It is now evident why the lymph glands that drain the testis (and ovary) are to be sought not in the groin but lateral to the aorta, between the renal artery above and the common iliac artery below.

During its ascent in prenatal life the kidney or metanephros climbed, as it were, up an arterial ladder the rungs of which passed from the aorta to the mesonephros (or middle kidney) which was atrophying. If the kidney fails to let go its hold of one or more of the lower rungs after it has grasped one or more of the upper ones, then the adult kidney possesses more than one renal artery. It is on this basis that accessory renal arteries are explained (*fig. 289B*).

The Testicular Vessels. The testicular arteries, one on each side, arise from the aorta just below the renal arteries

and run infero-laterally in the subperitoneal tissue to the deep inguinal ring.

The artery adheres to the peritoneum, except where crossed by the following parts of the grasto-intestinal apparatus: *on the right*, by the 3rd part of duodenum, the right colic and ileo-colic vessels, and the end of the ileum or the cecum; *the left*, by the 4th part of the duodenum, the inferior mesenteric vein, the left colic arteries, and the iliac part of the descending colon. The artery descends in front of the psoas fascia, crosses in front of the ureter and genito-femoral nerve, and at the deep inguinal ring it lies in front of the external iliac artery.

Further, the right artery crosses in front of the i. v. cava when it arises below the renal veins and behind the i. v. cava when it arises above the renal veins, for reasons given (pp. 291, 292).

Each artery is accompanied by its vein, lymph vessels, and nerves.

The right testicular vein ends in the i. v. cava; *the left vein* in the left renal vein. As a rule, the right and left veins have from one to three bicuspid valves in their abdominal portions, usually towards the upper end (George). *The lymph vessels* end in glands placed between the renal and common iliac arteries. *The nerves* are derived from segment Th. 10, the segment in which the umbilicus lies.

The Ovarian Vessels have a similar

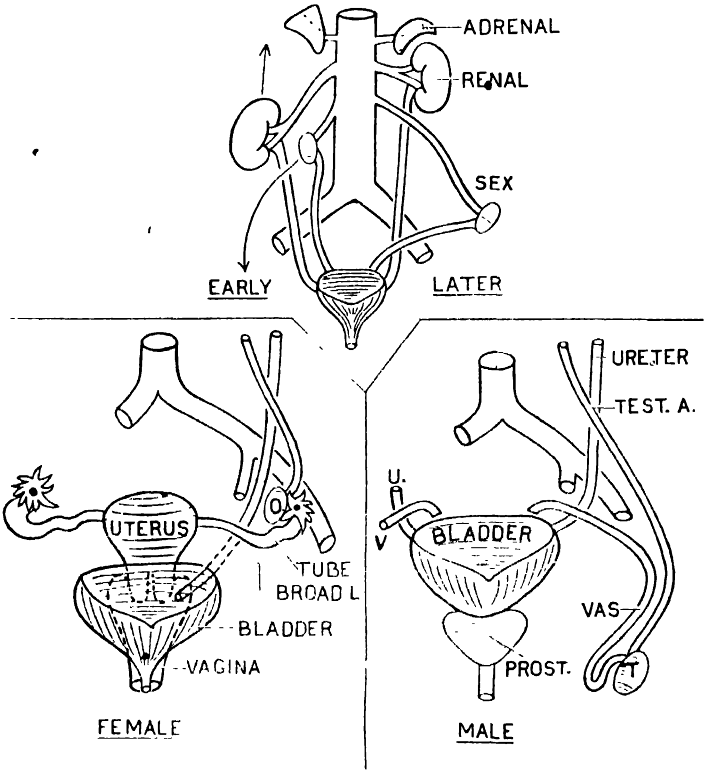


Fig. 283. The migrations of the kidney and sex gland. Ultimately the relationship of the ovarian vessels and uterine tube to the ureter is comparable to that of the testicular vessels and vas deferens to the ureter; that is, the vessels and duct in both sexes cross in front of the ureter.

course. They, however, cross the external iliac vessels $\frac{1}{2}''$ in front of the ureter, traverse the infundibulo-pelvic ligament, and thus enter the broad ligament.

The Vas Deferens runs a short subperitoneal course in the abdomen proper. From the deep inguinal ring it curves medially and downwards round the inferior epigastric artery, crosses the external iliac vessels, and enters the pelvis.

The Adrenal or Suprarenal Glands (*fig. 284*), a right and a left, overlap the upper ends of the kidneys. They are crescentic in shape and very friable. The glands are situated one on each side of the coeliac artery, and, as the coeliac ganglia alone intervene, they are less than an inch from the artery; indeed, their medial borders are exactly 2″ apart. A peak added to the right gland converts its crescentic form into a triangular one.

Development. Each gland is composed of two parts: an outer golden cortex and an inner vascular medulla. The cortex is of mesodermal origin; the medulla is of ectodermal. Originally, the gland consisted of cortical material only; later, sympathetic nerve cells and nerve fibers, derived from the coeliac ganglia, travelled along the adrenal vessels, penetrated the cortex, and gave rise to the medulla.

Function and Surface ***Anatomy.*** This reference to development will remind you that the hormone, *adrenalin*, which reinforces the action of the sympathetic nervous system, is derived from the medulla of the gland—the cortex is concerned with the metabolism of salts and water. It will also suggest that a methodical way to find the glands is: (a) to locate the coeliac artery between diaphragm and pancreas, (b) next to trace the fibers of the coeliac plexus from the coeliac artery, which they encircle, to the tough, nodular coeliac ganglia on each side of the artery, and (c) then to follow the slender nerve fibers from the ganglia to the adrenals (*fig. 284*). Further, it will assign the ganglia and the adrenals to the level of the coeliac artery (i.e., the height of a vertebra and disc above the transpyloric plane) and will make it fairly obvious that behind them are the crura of the diaphragm.

Relations. Behind, lie the crura of the diaphragm. *In front,* they were

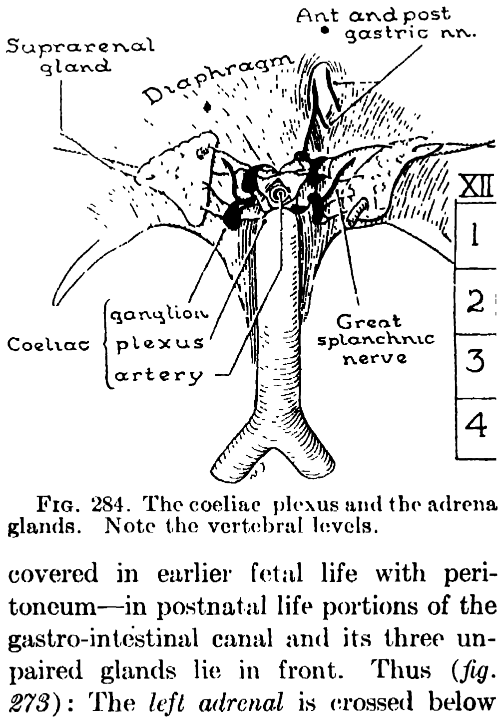


FIG. 284. The coeliac plexus and the adrena glands. Note the vertebral levels.

covered in earlier fetal life with peritoneum—in postnatal life portions of the gastro-intestinal canal and its three unpaired glands lie in front. Thus (*fig. 273*): The *left adrenal* is crossed below by the pancreas and the splenic artery, elsewhere it is separated from the stomach by the lesser sac; the spleen may reach its upper end. The ***right adrenal*** is covered either directly or indirectly by the liver. Now, embedded in the bare area of the liver is the inferior vena cava; and since the inferior vena cava is here an inch wide and lies half the width of the aorta from the median plane, it necessarily projects more than an inch

from that plane, so, it follows that the vein covers the right coeliac ganglion and overlaps the medial part of the right adrenal gland (*fig. 274*). The gland, however, extends below the bare area of the liver and there, lying at the mouth of the lesser sac, is separated from the inferior surface of the liver by peritoneum of the greater sac. The lower layer of the coronary ligament (hepato-renal ligament) is reflected on to it.

At birth the adrenal gland covers nearly the upper half of the kidney; in the adult it lies at the upper pole and along medial border above the hilum, some fat intervening.

The adrenal does not require to follow the excursions of the kidney. In fact, its association with the kidney is accidental.

Nerves. Numerous tenuous twigs from three arteries converge on each gland (a) from the adrenal artery proper, which springs from the aorta, (b) from the inferior phrenic artery above, and (c) from the renal artery below.

A single large adrenal vein leaves the anterior surface of each gland: the right vein ascends to the i.v. cava; the left vein descends to the left renal vein.

The greater and lesser splanchnic nerves pierce the crura of the diaphragm and pass to the respective coeliac ganglia. A branch of the posterior gastric nerve, containing fibers from both vagi, divides and likewise passes to both ganglia.

The half dozen nerve filaments that pass to the adrenal gland are probably derived from the lesser and least splanchnics and from the 1st and 2nd lumbar sympathetic ganglia.

The Kidneys. Each kidney is about $4\frac{1}{2}$ inches long and weighs about $4\frac{1}{2}$ ounces. It possesses *two surfaces*, an anterior and a posterior, separated from each other by a "circumferential" border. In reality the anterior and posterior surfaces face antero-laterally and postero-medially, because the kidneys are applied to the muscles that clothe the sides of the vertebrae. The circumferential border may be subdivided into two borders, a medial and a lateral, and *two poles*, an upper and a lower. The upper pole is generally a little thicker and nearer the median plane than the lower; so, the long axis of the gland is directed infero-laterally. The intermediate third of the medial border presents a cleft, the *hilum*

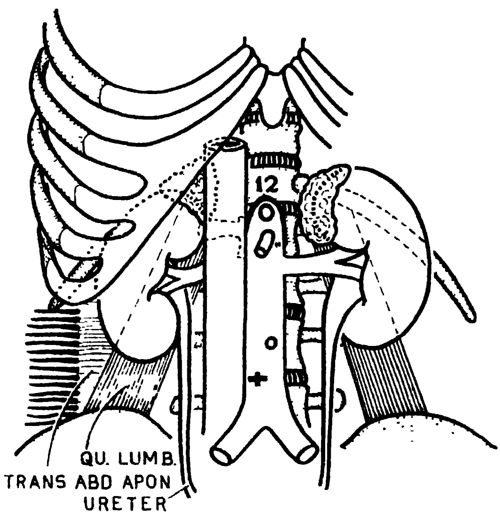


FIG. 285. Showing the relations of the adrenals, kidneys and ureters to the anterior and posterior surfaces of the body.

or door, which leads into a cavity, the *renal sinus*. (*Fig. 285*).

Passing through the hilum into the sinus are the *pelvis* or expanded upper end of the ureter, the renal vessels and nerves, and some fat.

As at the porta or hilum of the liver, so here at the hilum of the kidney, the artery is placed between the vein and the duct (i.e., portal vein, *hepatic artery*, hepatic duct; renal vein, *renal artery*, pelvis of ureter). At the liver, however, the vein is posterior; at the kidney it is anterior. Though the hepatic and renal arteries

are variable, it is usual for the renal artery to divide at the hilum of the kidney into three branches; of these, two pass in front of the pelvis of the ureter and one passes behind its upper part.

Above the hilum, the adrenal gland is in contact with the medial border and upper pole; below the hilum, the ureter is close to the medial border.

The kidney has a *fibrous capsule* which is easily removed. Like other abdominal organs the kidney lies in the extra-peritoneal fatty tissue. In the midst of this fatty tissue there is a tough areolar membrane, the *renal fascia,* which splits to enclose the kidney and a certain quantity of fat, the *perinephric fat.* The two layers of fascia do not blend below, so, the kidneys can move downwards with the diaphragm during inspiration; neither do they blend medially but pass in front of and behind the renal vessels, aorta, and inferior vena cava to unite indefinitely with the respective layers of the opposite side. Above and laterally the two layers of fascia blend and fade away.

Surface Anatomy (*fig. 285*). The right kidney does not rise quite so high as the left kidney. Apparently the presence of the liver is responsible for arresting the upward migration of the right kidney just as it arrests the downward expansion of the right lung. The *lower poles* of the kidneys lie an inch or less above the transumbilical plane, which is at the level of the 3–4 intervertebral disc. The kidneys are $4\frac{1}{2}$ inches long; so, their *upper poles* must lie about $5\frac{1}{2}$ inches above the transumbilical plane. If you will measure, you will find these points to be behind the 7th costal cartilages.

The adrenal gland, which caps the kidney and lies along its medial border, has its centre at or above the level of the celiac artery and, therefore, at the disc between the 12th thoracic and 1st lumbar vertebrae. It follows that the kidney extends from the level of the upper part of the 3rd lumbar vertebra upwards beyond the 2nd and 1st lumbar vertebrae to the level of the 12th thoracic vertebra, and, therefore, beyond the 12th rib. Its *medial border* lies from the median plane nearly as far as the length of right renal vein ($1\frac{1}{2}''$) + the breadth of the i. v. c. ($1''$) + half the breadth of the aorta ($\frac{1}{2}''$) = 3 inches in all. But, when allowances are made for the obliquity of the vessels and the depression of the renal hilum, the distance from the median sagittal plane will be seen to be less than two inches. The transpyloric plane crosses the upper part of the hilum.

At the back the kidney extends from a point one or two fingers' breadth above the highest part of the iliac crest, which is on a level with the spine of the fourth lumbar vertebra, upwards to or almost to the eleventh rib.

Anterior Relations. The primitive anterior relation was peritoneum, separated above by the adrenal gland. The thick cortex of the adrenal atrophied after birth leaving the gastro-intestinal canal and its three unpaired glands in sole possession of the field. When you explored the peritoneal cavity, you palpated the lower poles of the kidneys in the angles of the right colic and left colic flexures (*fig. 217*); above the right colic flexure you palpated the right kidney in the hepato-renal pouch (*fig. 229*); above the left colic flexure and phrenico-colic ligament you palpated the left kidney behind the spleen as far medially as the lieno-renal ligament. The anterior relations are shown in figures 256, 273.

The methodical and systematic way

of arriving at the anterior relations of the different parts of the three paired gland apparatus is to enumerate the parts of the gastro-intestinal apparatus (*fig. 218*), then to discard all impossible parts, and to consider carefully all likely parts, together with their vessels and ducts. This is done for the kidneys in table 12, the appropriate items being selected from the middle column.

TABLE 12

The Anterior Relations of the Kidneys

ANTERIOR RELATIONS OF THE RIGHT KIDNEY	PARTS OF G. I. TRACT AND ITS 3 UNPAIRED GLANDS	ANTERIOR RELATIONS OF THE LEFT KIDNEY
	Oesophagus	
	Stomach	(Lesser sac intervening)
	1st Duodenum	
(Bare area)..................	2nd Duodenum	
	3rd Duodenum	
	Duodeno-jejunal junction	
(Greater sac intervening)	Jejunum	(Greater sac intervening)
	Ileum	
	Appendix	
	Cecum	
	Ascending colon	
(Bare area)...	Hepatic flexure	
	Transverse colon	
	Splenic flexure.. . .	(Bare area)
	Descending colon	
	Pelvic colon	
(Bare area)	Rectum	
Hepato-renal lig.	Liver	
(Greater sac intervening)	Pancreas	(Bare area)
	Spleen	(Greater sac intervening)
	Branches of:	
Asc. branch of right colic vessels.....	Celiac a.	Splenic artery and vein with pancreas
	S. Mesenteric a.	
	I. Mesenteric a	Asc. branch of left colic vessels
	Bile ducts	
	Pancreatic ducts	
	Parts of the 3 paired gland system	
In infancy.........	*Adrenal glands*	In infancy
	and vessels	
	Kidneys	
	and vessels	
	and ureters	
	Testes or ovaries	
	and vessels (testicular or ovarian)	
	and ducts (vasa deferentia or uterine tubes)	

The middle column of this table contains a systematically arranged list of the various parts of (a) the gastro-intestinal tract and its three unpaired glands and (b) the three paired gland system; these constitute all the possible anterior relations of the right and left kidneys. From the knowledge you have acquired you should not have difficulty in selecting those structures lying in front of the right kidney and those in front of the left, indicated by dotted lines in the table, e.g., the oesophagus obviously is in front of neither kidney, the stomach is in front of the left (lesser sac of peritoneum intervening), the second part of the duodenum is in front of the right (over a bare area, that is, without intervening peritoneum), and so on.

The Posterior Relations belong to the roof and posterior wall of the abdomen (*fig. 301*). They are: (a) *Muscles:* The diaphragm, together with the medial and lateral arcuate ligaments from which it arises; the Psoas and Quadratus

Lumborum and, in the angle between them, the uncovered tips of the transverse processes of the 1st, 2nd, and (3rd) lumbar vertebrae; and, which is most apt to be forgotten, the posterior aponeurosis of the Transversus Abdominis. (b) *Nerves and Vessels:* Theoretically, branches of nerves Th. 12 and L. 1, 2, and 3 might pass posteriorly because the kidney lies

encountered in approaching a kidney from behind.

The Kidney on Longitudinal Section. When a kidney is divided with a sharp knife into anterior and posterior halves, its cut surface is seen to possess six or more smooth, darkish, longitudinally striated, triangular areas known as the pyramids (*fig. 287*). Each *pyramid* is seen to have a free, rounded apex or

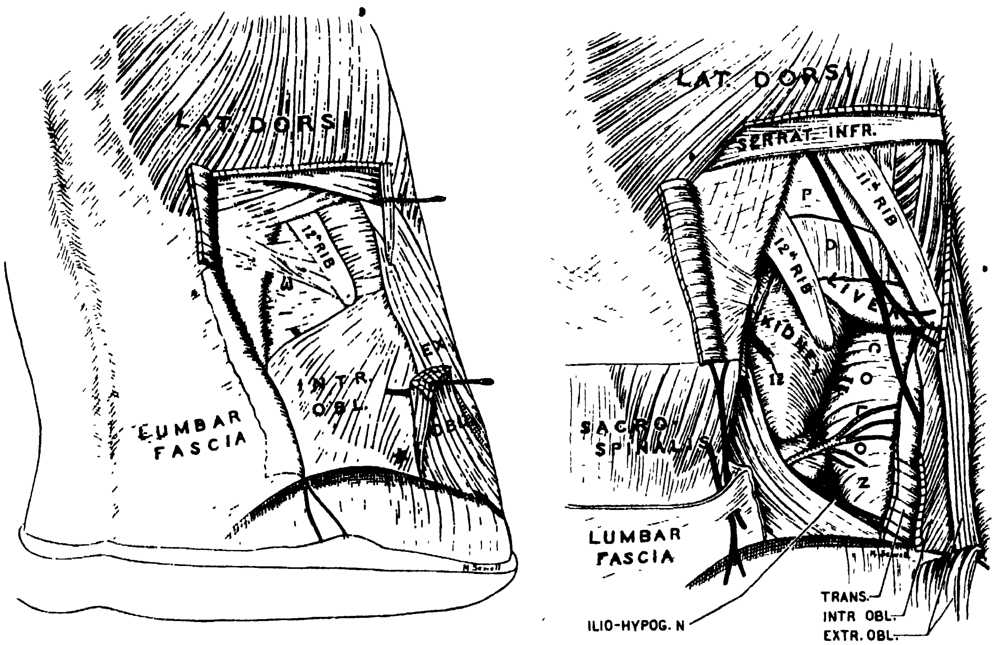


FIG. 286. Two stages in the dissection to expose the kidney from behind. P = lower limit of pleura; D = diaphragm; ★ = site of lumbar triangle. (Dissected by C. Storton.)

abreast of the corresponding vertebrae, but the only branches that actually do so are from Th. 12 (subcostal nerve) and L. 1 (ilio-hypogastric and ilio-inguinal nerves). Branches from L. 2 and 3 descend with a more vertical trend and lie medial to the normally placed kidney.

The subcostal artery, in company with its nerve, and the fourth lumbar artery pass in front of the Quadratus; whilst the 1st, 2nd, and 3rd lumbar arteries pass behind the Quadratus, and might be

papilla which projects into the renal sinus, a *body* or main portion, and from the *base* of the pyramid radiations, the *medullary rays*, occupy the cortex of the kidney and extend to the surface. A papilla, a body, and a series of medullary rays constitute a complete pyramid.

The outer or surface layer of the kidney is the *cortex*. It is the part that lies superficial to the bases of the pyramids and it comprises the entire outer one-third of the kidney substance. It looks

granular. Cortical tissue also fills the areas between the pyramids and is there known as the *renal columns* of Bertin.

The striated appearance of a pyramid is due to the fact that its component parts [descending and ascending limbs of the loops of Henle, collecting tubules, papillary ducts of Bellini, and blood vessels] converge on the papilla.

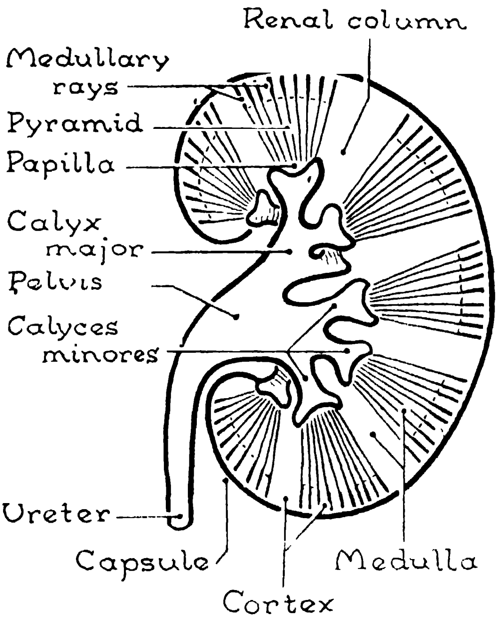


FIG. 287. The macroscopic structure of the **kidney** (seen on longitudinal section).

The cortex and the renal columns look granular because they are composed of structures [glomeruli, convoluted tubules, and blood vessels] cut across in various planes.

Renal Vessels and Nerves. The blood supply of the kidney is peculiar in that all or almost all of the blood passes through the glomerular capillaries where it is purified before it passes through a second set of capillaries from which it nourishes the kidney substance. Trueta and his associates seem recently to have demonstrated, in certain cases of shock, that all the blood entering the kidney may temporarily be shunted through juxtamedullary glomeruli into the medulla thereby throwing the cortex out of action, sometimes with fatal results.

The renal veins may be said to contain the purest blood in the body.

The Renal Arteries, one for each kidney, arise from the sides of the aorta $\frac{1}{4}''$ below the superior mesenteric a., which in turn arises $\frac{1}{4}''$ below the coeliac a.; hence, their vertebral level is L. 1–2 (*figs. 285, 290*). They are large, nearly horizontal, and equal in length (the veins are unequal). (See also pp. 61, 62.)

The immediate *anterior relations* of the renal arteries are the renal veins, and on the right side, the i.v.c. is also anterior all covered with an areolar sheet (*fig. 280*). Anterior to these, on the *right side*, are the head of the pancreas and the 2nd part of the duodenum, covered behind with an areolar sheet; on the *left side*, the body of the pancreas in which are embedded the splenic a. and v., covered behind with a (second) areolar sheet. The *posterior relations* of each renal artery are the crus of the diaphragm and the Psoas, areolar sheets intervening.

The Renal Nerves are probably derived from T. 12, L. 1 and 2. (For details see p. 63.)

The Pelvis of the Ureter (pelvis of the kidney) (*fig. 288*) is the expanded, funnel-shaped, upper end of the ureter. It lies partly within the renal sinus and partly outside it. Traced towards the kidney it is seen to divide into two stalks, the *upper* and *lower calyces majores*, with sometimes a third or *central calyx*. Each major calyx divides into three or four goblet-shaped *calyces minores* into each of which one or two papillae project. A dozen or more papillary ducts open on to each papilla.

The Ureter or duct of the kidney is 10

inches long. Its upper half is in the abdomen; its lower half is in the pelvis. Its abdominal part extends almost perpendicularly from the lower part of the hilum of the kidney (less than two inches from the median plane) to the bifurcation of the common iliac artery (one-third of the distance from aortic bifurcation to the midinguinal point) where it crosses the external iliac vessels and enters the pelvis. It lies in the subperitoneal areolar tissue and you should note that, when the peritoneum is mobilized, the ureter moves with it just as do the testicular vessels ileo-colic arteries, the root of the mesentery, and the end of the ileum. On the *left side* they are: the left colic arteries and the mesentery of the pelvic colon. The ureter descends on the Psoas fascia and crosses the genito-femoral nerve. The i. v. cava is close to the medial side of the right ureter; the inferior mesenteric vein is close to the medial side of the left ureter.

Arteries. The pelvis and the ureter possess a longitudinal anastomosing network of arteries derived from the renal artery above and the vesical artery below. This is re-inforced at its middle by an aortic or testicular (ovarian) or common iliac branch.

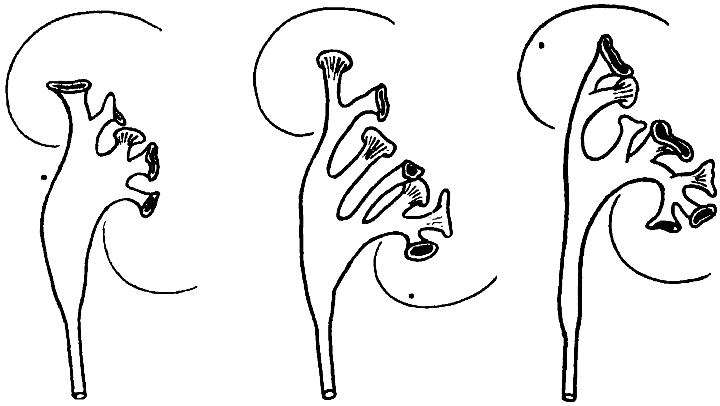


FIG. 288. Sketches of casts of the pelvis of the ureter (kidney).

and vas deferens. In embryonic life the ureter was subperitoneal from end to end. When the testis (or ovary) descended it drew its vessels across the front of the abdominal part of the ureter and its vas deferens across the front of the pelvic part (*fig. 283*). (Similarly, the uterine tube crosses the pelvic part in the female.) Its terminal portion pierces the postero-lateral angle of the bladder, surrounded by a leash of vesical veins. [In the female the uterine artery also crosses it at the lateral fornix of the vagina.] Otherwise its anterior relations belong to the gastro-intestinal canal. On the *right side* they are: the 2nd part of the duodenum, the right colic and

Nerves. Like the arteries, the nerves are derived from the renal and intermesenteric plexuses above; from the pelvic plexus (inf. hypogastric plexus) below; and from the testicular and hypogastric plexuses in between (T. 12, L. 1 and 2).

Anomalies (*fig. 289*). Much the commonest gross anomaly of the urinary tract is a *bifid ureter* and pelvis, the result of premature division of the ureteric bud in the fetus. The condition is generally incomplete and unilateral and the ureter is commonly constricted at the point of

fission. When there is a completely double ureter, the ureter from the lower part of the kidney enters normally, the ureter from the upper part enters lower down, sometimes into other parts of the u. g. tract, e.g., the floor of the urethra, or roof of the vagina or uterus, or into the vas deferens or seminal vesicle. This is one cause of incontinence of urine.

A *postcaval ureter* is a right ureter that winds spirally around the inf. vena cava. Only 27 have so far been reported (Pick and Anson).

About 3 per cent of kidneys have *two renal arteries* arising from the aorta, of which one usually goes to the upper or lower pole. *Fused kidneys:* in 1 in 700 persons the right and left kidneys are fused, generally at their lower poles, and form a horse-shoe kidney. The ascent may be arrested by the inferior mesen-

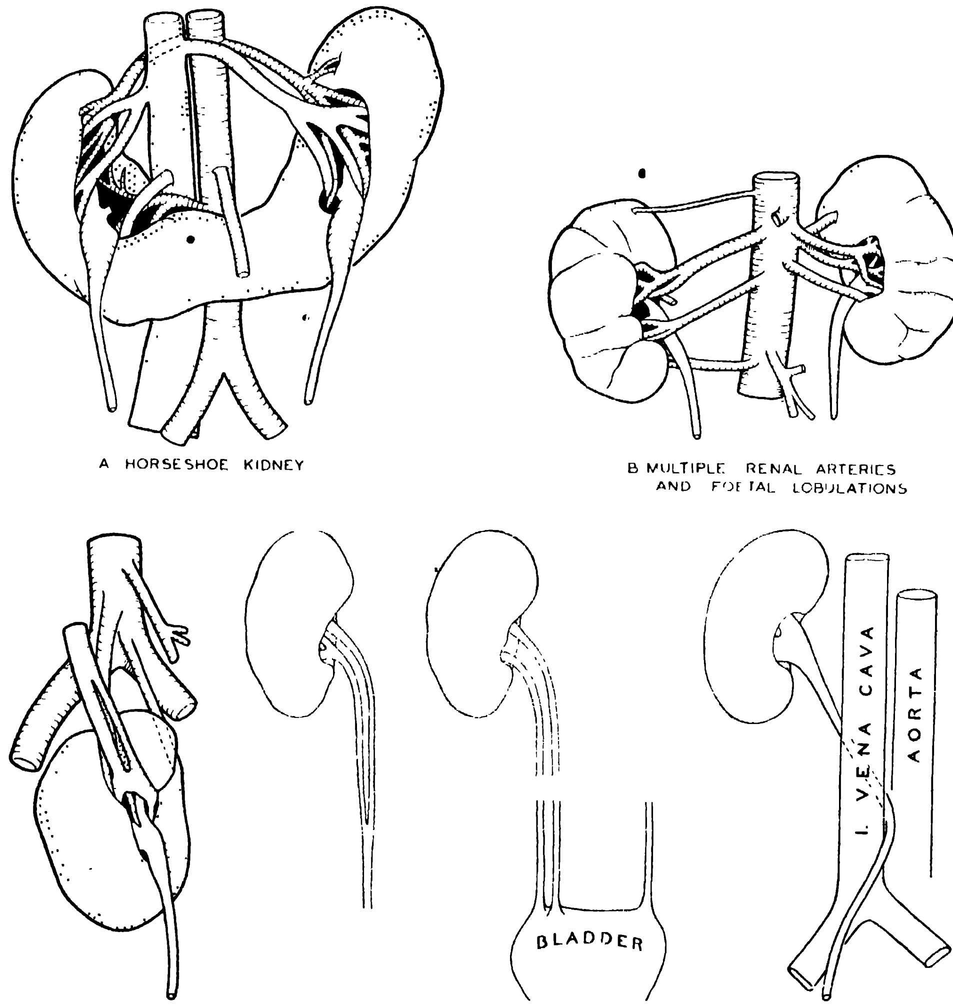


FIG. 289. Anomalies of the kidneys and ureters.

teric a. crossing in front of the isthmus. *Congenital absence of kidney and ureter* or *rudimentary kidney with ureter* occur with the same frequency as horse-shoe kidney. The kidney on one side may be *double* with independent ureters and vessels. One or other kidney may migrate across the median plane. A kidney may *fail to ascend,* and be lodged in the pelvis and supplied by the iliac and other arteries of low origin. The surface of the kidney commonly retains the *fetal lobulation* present at birth and well seen in the cow. The anterior lip of the sinus is often undeveloped. *A congenital cystic kidney* results when the duct system and the secreting parts of the kidney fail to unite.

THE GREAT VESSELS OF THE ABDOMEN

The great vessels are the abdominal aorta, the inferior vena cava, and the common, external, and internal iliac arteries and veins.

The Abdominal Aorta. It is remarkable that this great vessel and its continuation, the *median sacral artery,* should lie in contact with and beat against the bare vertebral column without any soft fatty or fleshy cushion intervening; but such is the case. The aorta enters the abdomen in the median plane by passing behind the diaphragm at the level of the disc between vertebrae T. 12 and L. 1, which is, of course, the height of a vertebra above the transpyloric plane. It ends in front of the fourth lumbar vertebra, about three quarters of an inch below and to the left of the umbilicus, by bifurcating into the right and the left common iliac artery (*fig. 300*). On each side of the aorta stretch the legs or crura of the diaphragm. The right crus, being the longer and stronger, descends to the 3rd lumbar vertebra; the left crus to the 2nd lumbar vertebra.

Each common iliac artery bifurcates into an internal iliac and an external iliac artery. The course of the common and external iliac arteries is indicated on the skin surface by a curved line joining the site of the aortic bifurcation to the mid-inguinal point. The upper third, or 2″, of this line marks the common iliac artery; the lower two-thirds, or 4″, the external iliac artery. It is at the junction of the upper one-third with the lower two-thirds that the bifurcation into external and internal iliac arteries takes place. At this point the ureter crosses the external artery and enters the pelvis in front of the internal iliac artery.

When you consider that the abdominal aorta crosses only 3½ vertebrae and discs, you are not surprised that the common and external iliac arteries together exceed it in length (142 mm.: 135 mm.).

The Common and External Iliac Arteries pass from the aortic bifurcation across the front of the body of the 5th vertebra, along the medial border of the Psoas, and finally along the front of the Psoas to the midinguinal point where the name changes to femoral artery. The veins and arteries are loosely bound together in the extraperitoneal tissue. The veins lie within the bifurcation of the arteries, as shown in figure 290. The common iliac veins end and the i. v. cava begins behind the right common iliac artery.

Branches. Two branches arise from the external iliac artery as it passes behind the inguinal ligament——the *inferior epigastric* and the *deep circumflex iliac arteries* (p. 214). The corresponding veins end in the external iliac veins.

The Collateral Branches of the Abdominal Aorta are:

A. Coeliac a. S. mesenteric a. I. mesenteric a.	To the G.I. canal and the 3 unpaired glands.

B. **Adrenal aa.** } To the
Renal aa. } 3 paired glands.
Testicular aa.

C. Phrenic aa. } To the
Lumbar aa. (1–4) } roof and walls
Median sacral a. } of the abdomen.

aorta and is also unpaired; the other branches are paired.

The celiac artery and the roots of the s. mesenteric and i. mesenteric arteries project forwards from the aorta, like pegs, and prevent upward and downward

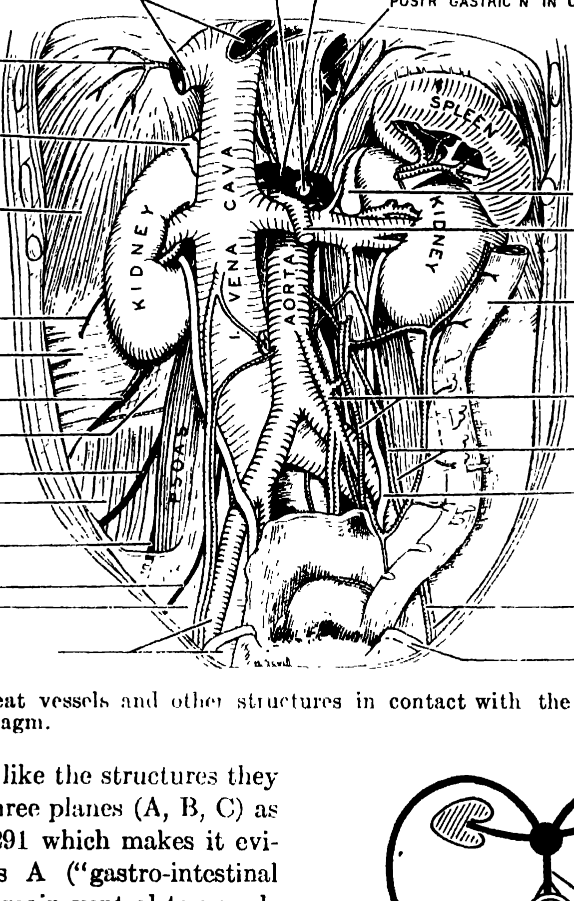


FIG. 290. The great vessels and other structures in contact with the posterior abdominal wall and the diaphragm.

These arteries, like the structures they supply, occupy three planes (A, B, C) as shown in figure 291 which makes it evident that vessels A ("gastro-intestinal plane") always remain ventral to vessels B ("three paired gland plane") and that these in turn remain ventral to, or within the embrace of, vessels C ("body wall plane").

A. The three arteries to the gastro-intestinal plane arise from the front of the aorta and are unpaired; the median sacral artery arises from the back of the aorta and is also unpaired; the other branches are paired.

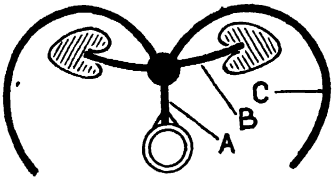


FIG. 291. The three "vascular planes." A = "G-I tract & Co."; B = "U-G tract & Co."; C = body wall. (See fig. 292.)

displacement of certain structures that cross the median plane (*fig. 292A*).

The Celiac Artery originally arose at the level of the 7th cervical vertebra, but

when the lungs developed and depressed the diaphragm, the diaphragm in its turn forced the stomach and the celiac artery downwards; so, now the median arcuate ligament, which unites the two crura of the diaphragm, rests upon the celiac artery and the crura are astride it (*fig. 292*). Its level is, therefore, that of the disc between 12th thoracic and 1st lumbar vertebrae, which is a segment above the transpyloric plane. The artery may be regarded as preventing ascent of the pancreas, which crosses below it.

origin $1\frac{1}{2}''$ above the aortic bifurcation, and $\frac{3}{4}''$ above the umbilicus, and therefore in front of the 3rd lumbar vertebra. It would arrest the ascent of a horse-shoe kidney. Its origin is overlapped by the 3rd part of the duodenum.

B. The arteries to the three paired glands arise close together, thus:

The Renal Artery (*fig. 292 B*) runs behind the renal vein and, therefore, arises just below the superior mesenteric artery.

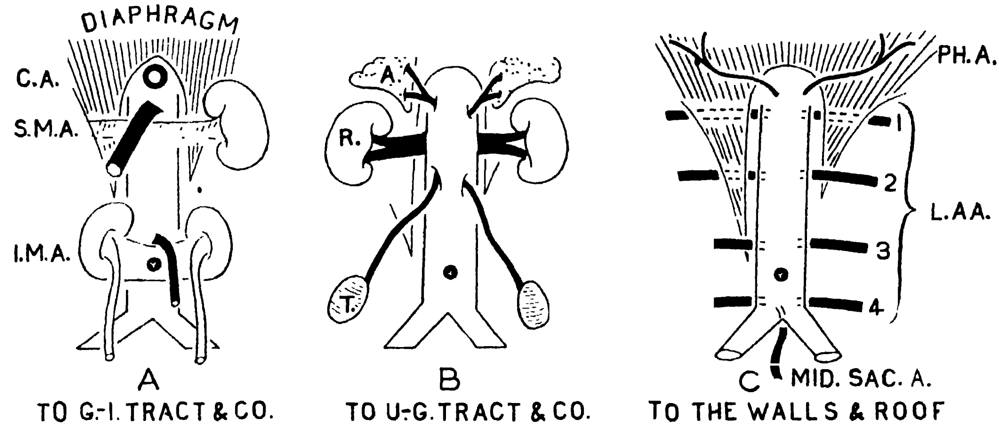


FIG. 292. The branches of the abdominal aorta arranged according to the planes they occupy (see fig. 291 A, B and C).

The Superior Mesenteric Artery takes origin just below the celiac artery, and therefore behind the neck of the pancreas, and therefore behind the splenic vein, which is embedded in the pancreas. It would prevent ascent of the left renal vein, which crosses the aorta close below it. The left renal vein may, indeed, be regarded as clamped between the root of the s. mesenteric a. and the aorta like a nut within nut crackers. The artery passes caudally in front of the left renal vein, and the head of the pancreas, and 3rd part of the duodenum and enters the root of the mesentery.

The Inferior Mesenteric Artery takes

The Adrenal Artery arises just above the renal artery.

The Testicular (or *Ovarian*) *Artery* arises just below the renal artery.

C. From their inception the phrenic, lumbar, and median sacral arteries are part either of the roof or of the wall of the abdomen. That is to say, no organ, vessel, or nerve intervenes between them and the roof or wall (*fig. 292 C*).

The (*Inferior*) *Phrenic Artery* arises beside the celiac artery and passes at once to the diaphragm which it never leaves. Though but a small vessel, it attempts much; not only does it assist in supplying the diaphragm, which is the

most important voluntary muscle in the body; it also sends accessory twigs to the liver, adrenal gland, and oesophagus. The hepatic twigs enter the bare area of the liver on the right side, and the fissure for the lig. venosum on the left. The oesophageal twigs pass through the oesophageal opening in the diaphragm.

In embryonic life three arteries supplied each adrenal gland. The most cranial of these subsequently sends a branch to the diaphragm and becomes the (inferior) phrenic artery; the most caudal sends a branch to the kidney and becomes the renal artery; and the intermediate vessel is known as the adrenal artery proper.

The Lumbar Arteries. There is a pair of lumbar arteries for each of the 5 lumbar segments, but only four pairs succeed in arising from the aorta since it ends at the fourth lumbar vertebra. The 5th pair, called the *ilio-lumbar arteries*, spring from internal iliac arteries. The lumbar arteries hug the bodies of the vertebrae and pass behind the sympathetic trunk and the Psoas The upper ones pass behind the crura also, and on the right side all pass behind the i. v. cava.

The Median Sacral Artery is the continuation of the aorta. It descends in the median plane in contact with the fifth lumbar vertebra and sacrum and, therefore, behind the left common iliac vein. In lower mammals it is the anterior caudal artery and it supplies the tail.

So, the phrenic, lumbar, and median sacral arteries are conceived on the body wall or on the roof of the abdomen and there they pass their whole existence. The i. phrenic artery is developmentally a branch of an adrenal artery; and the median sacral is the continuation of the aorta; so, group C is miscellaneous. It has no common morphological basis.

The Inferior Vena Cava (i. v. c.) begins in front of the 5th lumbar vertebra, below and to the right of the aortic bifurcation, where it is crossed anteriorly by the right common iliac artery. Above, it pierces the central tendon of the diaphragm at the level of 8th (or lower) thoracic vertebra, which on the surface corresponds to a point on the right sixth costal cartilage half-an-inch from the side of the sternum Half-an-inch higher it joins the right atrium of the heart. It extends, therefore, across eight vertebrae and is much longer ($8\frac{1}{2}$ inches long) than the abdominal aorta which crosses only three and a half. The external and common iliac veins lie within the fork of the corresponding arteries. The internal iliac veins pass out of the pelvis behind their arteries.

DEVELOPMENT (*figs. 293, 294*). The inferior vena cava is a composite vein of complex origin. Its course, relations, and tributaries, however, are rendered simple by reference to the elementary facts of its development; otherwise they are meaningless. The outstanding features are these: a longitudinal vein, the *posterior cardinal vein*, appears on each side of the vertebral column and travels through the abdomen and thorax to join with the similar vein, the *anterior cardinal vein*, from the head, neck, and upper limb, to form the *common cardinal vein* (duct of Cuvier) which ends in the sinus venosus of the heart. In addition to receiving the *somatic segmental veins* (lumbar and intercostal) from the body wall, the posterior cardinal vein receives the *veins from the three paired glands*, but it does not receive the veins from the *gastro-intestinal tract* and its three unpaired glands, nor has it anything to do with them. They return their blood via the

portal vein to the liver, and from the liver by the persisting right vitelline vein, which definitively become the terminal part of the inferior vena cava, to the heart, as described above (*fig. 258*).

Two cross-communications, of which one is the *left common iliac vein*, the other the *left renal vein*, divert the blood from the left posterior cardinal vein across the front of the aorta or its continuation, the median sacral artery, into the right posterior cardinal vein The newly formed cross-communication. Now, though this communication is referred to in postnatal anatomy as a portion of the left renal vein, you must think of it as *"the vein of the 3 left paired glands"*; for such it properly is.

A newly formed vessel sprouts from the right posterior cardinal vein about the level of the right and left renal veins, and connects it with the right vitelline vein behind the liver (*fig. 293 B, broken lines*). Thereafter, the long route

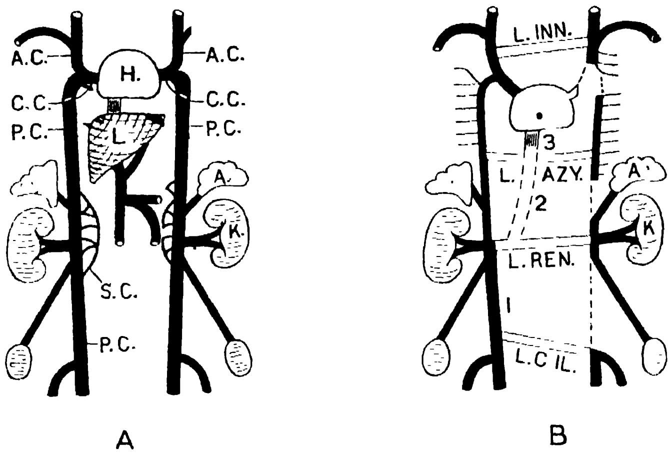


FIG. 293. The development of the inferior vena cava. (A) A. C.; P. C.; S. C.; C. C.; = anterior, posterior, sub-, and common cardinal veins. (B) 1 = postrenal segment of the i. v. cava; 2 = new connection; 3 = prehepatic segment. Note that the left renal vein is the vein of "the three left glands."

segment of the left posterior cardinal vein between the left common iliac and left renal veins is thereby rendered superfluous. It ceases to exist, except in rare instances when it persists as the post-renal portion of a left inferior vena cava. Several cross-communications connect the *left lumbar veins* across the back of the aorta to the right cardinal vein (*fig. 579*).

From the foregoing remarks you will appreciate that whilst the veins of the 3 right paired glands join the right cardinal vein independently, those of the 3 left paired glands join it collectively through to the heart via the prerenal (thoracic) portion of the right posterior cardinal and common cardinal veins is abandoned in favor of the shorter route via the newly formed connection and the prehepatic part of the right vitelline vein. These three (1) the right cardinal vein as far as the entrance of the renal veins, (2) the new connection, and (3) the terminal or prehepatic portion of the right vitelline vein, are the essential parts of the (right) inferior vena cava.

It is important to appreciate that (1) the post-renal segment of the i. v. cava lies on a posterior plane—the plane of

the three paired glands, that (3) the prehepatic segment lies on an anterior plane—the plane of the gastro-intestinal tract and the three unpaired glands, and that (2) the new connection connects the two planes.

If you pull forwards the right kidney, you will see a small vein, about the size of a lumbar vein, leave the back of the i. v.

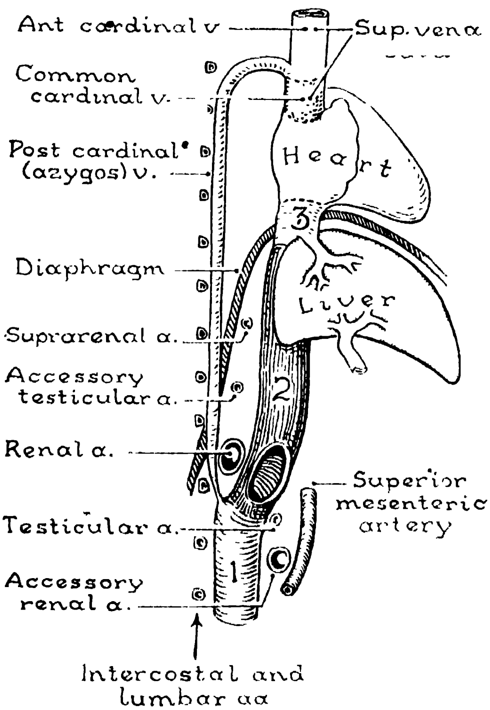


FIG. 294. Scheme of the development of the inferior vena cava, explaining its relationship to the arteries that cross it, side view.

cava, at or just caudal to the site of entrance of the renal veins, and pass headwards through the crus of the diaphragm. This is a vestige of the prerenal portion of the right p. cardinal vein. In the thorax it largely becomes the azygos vein. The point to determine is that it lies on the same posterior plane as the postrenal portion of the i. v. c. for the simple reason that it was originally its headward continuation. Similarly, a vestige of the corresponding left p. cardinal vein passes from the back of the left renal vein through the left crus and joins the left hemiazygos vein.

Actually, the posterior cardinal vein is one of a series of three longitudinal intercommunicating veins (the posterior cardinal, supra-cardinal, and sub-cardinal) related to the primitive kidneys. Part of the supracardinal vein may be, and part of the subcardinal vein is, incorporated in the i. v. cava. Much academic interest has centered on these veins.

The Tributaries of the Inferior Vena Cava. These fall into the same three groups as the branches of the abdominal aorta:

A. *The blood from the gastro-intestinal canal* and from its 3 associated glands passes through the portal vein to the liver, and, after circulating in the liver, leaves it via the hepatic veins to enter the i. v. cava. When the liver is removed from the body, the open mouths of three large hepatic veins, issuing from the right, the left, and the caudate lobes, are seen pointing upwards as though ready to disgorge their contents through the last inch of the i. v. c. into the heart. And, when the portion of the i. v. c. embedded in the liver is slit up, the small orifices of a dozen or so minute hepatic veins are seen.

B. *The veins of the 3 paired glands:* On the right side the adrenal, renal, and testicular (or ovarian) veins enter the i. v. c. separately; on the left side they unite to form a common trunk, the so-called left renal vein, which crosses in front of the aorta immediately or slightly below the stem of the superior mesenteric artery and, therefore, behind the pancreas and splenic (artery and) vein. The right adrenal vein passes upwards; the left adrenal vein passes downwards; and

though shown in diagram 293 as ending in the p. cardinal veins, actually they end in the subcardinal (plexuses of) veins.

VARICOCELE, i.e., varicose testicular veins (p. 217), is a condition almost restricted to the left testicular (or ovarian) vein. In explanation of this, three mechanical reasons are advanced: (1) that the *left testicular vein* has less competent valves than the right vein— but this is not so (p. 276); (2) that the adrenalin-laden blood issuing from the *left adrenal vein* bathes the mouth of the left testicular vein causing it to contract—this explanation is ingenious; (3) that the *left "common" renal vein* is clamped between the root of the s. mesenteric artery and the aorta like a nut within nutcrackers; hence, in the erect posture, the intestines dragging on the s. mesenteric artery apply pressure; this retards the flow in all 3 veins, viz., left testicular, left adrenal, and left renal "proper"—this explanation has precedent, for the s. mesenteric artery (or root of the mesentery) has been shown to be capable of obstructing the duodenum (*fig. 264*).

C. *Of the veins of the body wall* the right and left (inferior) phrenic veins enter the i. v. c.; the left vein, however, commonly ends in the left renal vein.

The lumbar veins accompany their arteries. Those of both sides end in the i. v. c. or in some derivatives of the cardinal system of veins, the left crossing behind the aorta.

The right and left ilio-lumbar veins, which are the veins of the 5th lumbar segment, end in the right and left common iliac veins.

The median sacral vein ends in the left common iliac vein.

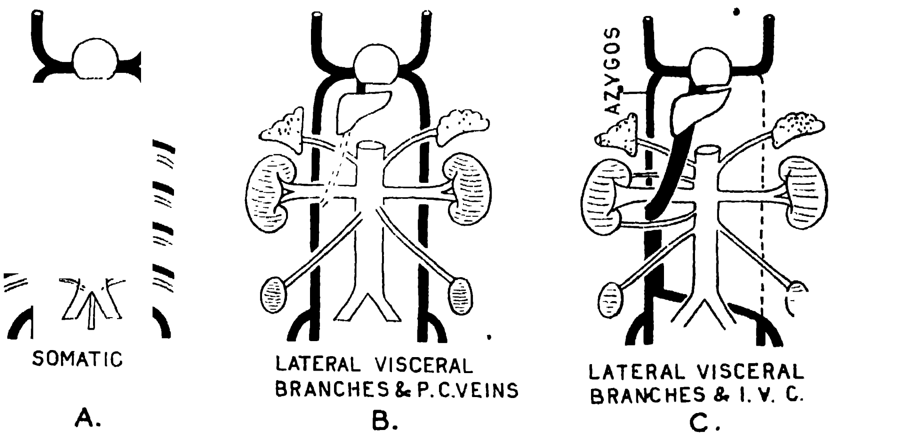


FIG. 295. Explaining the relationships of the branches of the aorta to the cardinal veins and subsequently to the i. v. cava. In C note the relations of the accessory renal arteries to the i. v. cava.

The Relationships of the Branches of the Aorta to the I. V. C. are explained on a developmental basis in figure 295.

A shows that the somatic segmental arteries (lumbar, ilio-lumbar, and intercostal) pass behind the cardinal veins in the embryo and, therefore, behind the inferior vena cava in the adult.

B shows that the arteries to the 3 paired glands pass in front of the cardinal veins. The (inf.) phrenic artery, being originally an adrenal artery, does likewise.

C shows the relations that the arteries to the 3 right paired glands bear to the composite vessel called the i. v. cava—

TABLE 13

The Great Vessels

	ANTERIOR RELATIONS				POSTERIOR RELATIONS
Name of vessel	G I canal, 3 unpaired glands their vessels and ducts		3 paired glands, their vessels and ducts	Other structures	Mainly parts of the body wall
Abdominal Aorta	Stomach (lesser sac intervening) Pancreas (body and uncinate process) and splenic vein and trans. colon and mesocolon Duodenum (3rd part) Root of mesentery Jejunum and ileum (greater sac intervening)		*Left renal vein* draining 3 left paired glands	Celiac and other preaortic plexuses	$3\frac{1}{2}$ vertebral bodies, discs and anterior longit. lig. Left lumbar veins
C. Iliac A.	Right	Left I. mesenteric a and v. Infr. l. colic a. and v.		Branches joining aortic to hypogastric plexus	5th lumbar body and ala of sacrum Sympathetic cord Lumbo-sacral cord Ilio-lumbar a. Obturator nerve *also on right side* Infr. vena cava
Ex. Iliac A.	End of Ileum ? Appendix ? Cecum	Pelvic colon and mesocolon	Ureter (male) V. deferens Testicular a. and v (female) Lig. teres uteri (Ovarian) a. and v. Genito-femoral n.		Psoas and its fascia
I. V. Cava	Liver (bare area) Mouth of lesser sac Duodenum (1st) Pancreas (head) Bile duct Accessory and main pancreatic ducts Duodenum (3rd part) *Mesentery* root and branches of s. mesenteric vv. Small intestine (greater sac intervening)	Portal vein Hepatic and gastroduodenal a. Bile duct	R. testicular (ovarian) a.	R. common iliac a.	*Above renal vein:* Diaphragm Adrenal gland Arteries to body wall and to 3 paired glands *Below renal vein:* Psoas and Crus and Vertebrae Sympathetic cord Arteries to body wall

those crossing its postrenal segment pass in front; those crossing its prerenal segment pass behind. So, the right testicular (or ovarian) artery passes in front;

the renal, adrenal, and also the inferior phrenic arteries pass behind, but of course they all cross on a plane anterior to the right p. cardinal vein.

Accessory renal arteries arising from the aorta below the renal vein pass in front of the i. v. cava; accessory renal arteries and testicular arteries arising above the renal vein pass behind.

All arteries and branches of arteries to the gastro-intestinal canal and its 3 unpaired glands that pass to the right of the median plane must cross in front of the i. v. cava e.g., the hepatic, gastro-duodenal, right colic, ileo-colic, and the superior mesenteric artery itself where it lies in the root of the mesentery.

Relationships. It would be folly to commit to memory the relationships of the great vessels when they can be arrived at by systematically passing in review the different parts of the G. I. Tract & Co., U. G. Tract & Co., Body, Wall and other possible structures, as is done in the Table 13.

THE AUTONOMIC NERVOUS SYSTEM WITHIN THE ABDOMEN

The autonomic nervous system within the abdomen is represented by:

(a) Sympathetic trunks, gray, and white rami communicantes and lumbar splanchnics.

(b) Prevertebral plexuses—celiac, intermesenteric, and hypogastric.

(c) Sympathetic communications—three (thoracic) splanchnic nerves.

(d) Parasympathetic communications—from vagi and pelvic splanchnics.

Sympathetic Trunk (*fig. 301*). In the abdomen the sympathetic trunk follows faithfully the anterior border of the Psoas. It lies, therefore, on the bodies of the vertebrae, the transversely running lumbar vessels alone intervening. It enters from the thorax with the Psoas behind the medial arcuate ligament and it passes into the pelvis behind the common iliac vessels. The *right trunk* is concealed by the i. v. cava, and by the right renal artery which crosses behind the vena cava, and by the testicular artery which crosses in front. The *left trunk* is crossed by the left renal vessels, the left testicular and the inf. mesenteric arteries, and by the pancreas. As a rule each trunk has four ganglia—not five—two probably having fused (*fig. 301*).

CONNECTIONS. Each trunk receives a *white ramus* from each of the upper 2 (or 3) lumbar nerves and sends one or more *gray rami* to each of the five lumbar nerves. These rami run laterally and backwards on the sides of the vertebrae either with the lumbar vessels or independently. About 4 medially running rami, *lumbar splanchnics,* go to the intermesenteric and hypogastric plexuses.

The Celiac Plexus. The *celiac ganglia* (*fig. 284*) are tough, nodular masses connected to each other by fibers that encircle the root of the celiac artery, the whole being known as the *celiac plexus,* or as the *solar plexus,* because its branches radiate like the rays of the sun. Each ganglion lies behind the lesser sac of peritoneum, between the celiac artery and the adrenal gland and, therefore, on the crus of the diaphragm. The i. v. cava largely conceals the right ganglion; the pancreas and splenic artery the left one.

The celiac plexus extends down the front of the aorta and is reinforced by the lumbar splanchnic nerves to form the *intermesenteric* and *hypogastric plexuses.* The intermesenteric lies in front of the aorta; the hypogastric lies within the bifurcation of the aorta and therefore in front of the left common iliac

vein and the 5th lumbar vertebra and disc (*fig. 296*).

From the celiac plexus fine branches stream into the adrenal gland.

Sympathetic Connections. The great splanchnic nerve is the size of a digital nerve proper. It pierces the crus abreast of the celiac artery and at once joins the celiac ganglion; the small splanchnic nerve pierces the crus just below and laterally and joins the ganglion; the smallest splanchnic nerve also pierces the crus and joins an offshoot of the celiac plexus, called the *renal plexus*.

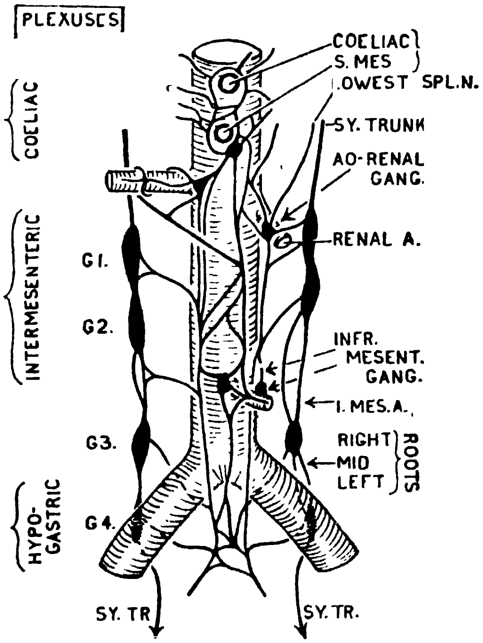


FIG. 296. The intermesenteric and hypogastric plexuses. (From a dissection by K. Baldwin.)

Parasympathetic Connections. Fibers of both *vagi*, via the posterior gastric nerve, join the celiac plexus and are distributed with the arteries (celiac, sup. mesenteric, renal, and testicular).

The *pelvic splanchnic nerve* ascends from the pelvis and passes through the hypogastric plexus to be distributed with the inferior mesenteric artery.

The vagi control the gut cranial to the left colic flexure; the pelvic splanchnics caudal to it. (*Fig. 764.*)

THE POSTERIOR WALL OF THE ABDOMEN PROPER

The gastro-intestinal apparatus is necessarily dissected before the three paired gland apparatus, and the three paired gland apparatus before the posterior abdominal wall. It is, however, by reconstructing from behind forwards that you best appreciate posterior relationships. Hence, when reviewing, it is well to read the sections on the posterior abdominal wall, diaphragm, and great vessels before studying the three paired glands, and to read the section on the three paired glands before studying the pancreas and duodenum.

Bony Parts. Medianly are the bodies, intervertebral discs, and transverse processes of the 5 lumbar vertebrae; laterally the wall extends from the 12th rib above to the pelvic brim below, and it is divided into upper and lower parts by the iliac crest. The *bodies* of the lumbar vertebrae increase in height and width from 1st-5th; so do the discs. The *discs* bulge, and the student commonly mistakes them for bodies until he happens to stick the point of his knife into them. The *transverse processes* project laterally at the levels of the upper halves of the bodies. The 3rd projects furthest; those above and below it project progressively less. The 5th is stout and conical and it projects upwards, backwards, and laterally. The *12th rib*, variable in length, curves downwards and laterally to about the level of the 2nd lumbar disc. The *iliac crest* curves upwards and laterally to the level of the middle or lower part of the 4th lumbar vertebra.

The region below the iliac crests is the *false pelvis*. It includes the alae of the sacrum and the iliac fossae described on page 328.

The Lumbar Vertebrae, 5 in number, have no rib facets and their transverse processes are not perforated.

The *body* is large, kidney-shaped, and flat above and below. The 1st is always deeper behind than in front, so is the 2nd as a rule, the 3rd is transitional (either deeper or less deep), but the 4th is always deeper in front, and the 5th is much deeper in front. The *pedicles* are directed backwards and laterally, as in the cervical region. There is a small superior (*inter*) *vertebral notch* on each side and a large inferior one. The *laminae* are thick and sloping, as in the cervical region, with the result that the *vertebral foramen*, which is triangular, is larger below than above. The *spine* is a thick oblong plate that projects nearly horizontally backwards and ends in a thickened posterior border. The *transverse processes* represent fused costal and transverse elements. They spring from the junction of pedicles and laminae and have a wide spread, the third having the widest (*fig. 300*). They may be regarded as ossifications extending into the posterior aponeurosis of the Transversus Abdominis and as such they are thin and bandlike; and, conforming to the shape of the rounded abdominal wall, they are directed slightly backwards. Their ends give attachment to the Transversus Abdominis aponeurosis (middle lamella of the lumbar fascia) and to the Quadratus Lumborum; hence, they are slightly thickened. Owing to the geographical position of the fifth vertebra, its processes extend on to the body and are conical (p. 332). The superior *articular processes* spring from the pedicles and, facing medially, grasp the inferior processes of the vertebra above, which spring from laminae and face laterally. The directions, however, gradually change, the inferior articular processes of the 5th lumbar vertebra facing nearly forwards.

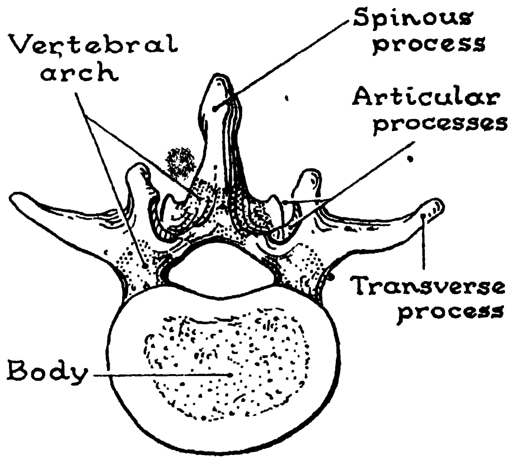


FIG. 297. A lumbar vertebra, from above.

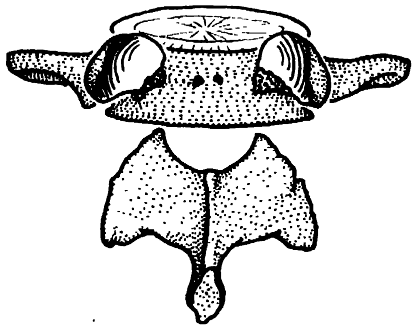


FIG. 298. The fifth lumbar vertebra is in two pieces in 5 per cent of individuals, rendering them liable to a deformity called spondylolisthesis.

The individual lumbar vertebrae can be identified by their articular processes.

VARIATIONS. (a) Five per cent of 5th lumbar vertebrae are in two parts—the spine, laminae, and inferior articular processes being detached (*fig. 298*). This is either the result of fracture or because the vertebra possesses accessory centers of ossification. The bodies,

losing the restraining influence of the inferior articular processes, tend to slip forwards (spondylolisthesis).

(b) The 5th lumbar vertebra is commonly partly sacralized (*fig. 299*).

(c) The two sides of the neural arch of the lower (or of any) vertebrae may fail to meet (spina bifida occulta).

Muscles. Iliacus, Psoas, Psoas Minor, Quadratus Lumborum, Transversus Abdominis, and Intertransversarii (*fig. 301*).

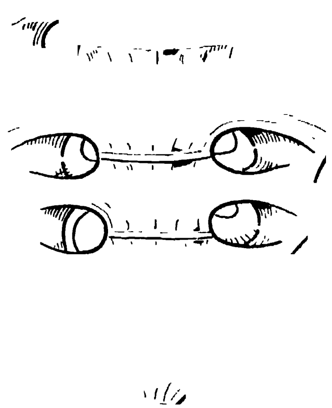


FIG. 299. The fifth lumbar vertebra is commonly partly sacralized.

The Iliacus covers the entire iliac fossa, and arises everywhere from it—except at its lowest part—and, it overflows on to the ala of the sacrum, from which and from the adjacent ligaments it derives a few fibers. Like the iliac fossa, it is fan-shaped. Because the iliac fossa is smooth and devoid of any roughness or ridge, it follows that the origin is fleshy. Since muscle fibers require to be from two to three times as long as the distance through which they contract, and as this requirement would not be fulfilled were the Iliacus to arise from the lower third of the fossa, it follows that though it overlies the lower third of the fossa it does not arise from it.

The fleshy fibers of the Iliacus are inserted into the lateral and anterior aspects of the Psoas tendon, and below the tendon a few of them pass directly to the femur.

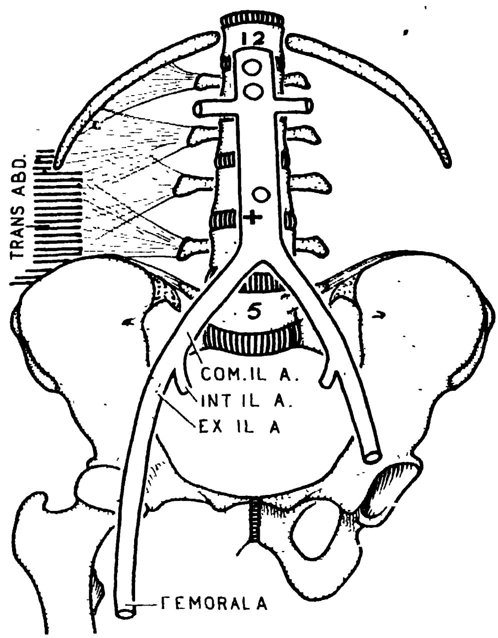


FIG. 300. Skeleton of the posterior abdominal wall; the Transversus Abdominis and its aponeurosis; and the great arteries (drawn to scale). + denotes the umbilicus.

The Psoas is the part of the Iliacus that has migrated above the iliac crest. Many muscles of the pectoral girdle migrate to the trunk; the Psoas is the only important muscle of the pelvic girdle to do so. The Psoas is a thick fleshy muscle comparable in size to the Biceps Brachii. It takes fleshy origin from the sides of the bodies and intervertebral discs of all the lumbar vertebrae, the attachments extending backwards on to the transverse processes and forwards as far as the sympathetic trunk. The muscle may be regarded as having moved

bodily headwards through half a segment because it encroaches on the lower half of the 12th thoracic vertebra and leaves the lower half of the 5th lumbar vertebra free. This being so, it follows that the anterior rami of the upper four lumbar nerves plunge into the substance of the Psoas when they emerge from the intervertebral foramina, and that the 5th anterior ramus escapes under the lower margin of the muscle. On the sides of the vertebral bodies, which are constricted like a waist, the lumbar vessels and the rami communicantes of the sympathetic trunk run dorsally protected by sheets of fascia which bridge them and afford the Psoas an uninterrupted origin (*fig. 301*).

The Psoas ends in a tendon which is inserted into a traction epiphysis—the lesser trochanter of the femur. The Psoas plays in the groove between the anterior inferior iliac spine and the ilio-pubic (ilio-pectineal) eminence prior to crossing the middle of the front of the hip joint. Its tendon therefore must lie posterior to its fleshy portion and it must be separated from the bony groove and capsule by a bursa, the *psoas bursa* (p. 456).

The Psoas assists the Rectus Abdominis to flex the lumbar segments of the column, and it assists the Iliacus to flex the hip joint.

The Psoas Minor is present in 50 per cent of 160 subjects, usually bilaterally. Its narrow flat tendon runs downwards in front of the Psoas; it blends with and greatly strengthens the fascia covering the Psoas, and it can generally be traced to a prominent ridge on the iliac portion of the pelvic brim. The presence of this ridge on a skeleton is evidence that a Psoas Minor was present in life. Like the Palmaris Longus and the Plantaris it is a vanishing muscle. In many lower mammals the Psoas Minor is larger than the Psoas itself. In the gibbon it arises from vertebrae Th. 12, L. 1, 2, and 3; in the three larger apes from Th. 12, L. 1 and (2); in man, when present, it arises from Th. 12 and L. 1. As a flexor of the pelvis on the spine, its value to the quadruped (e.g., rabbit) when running and to the ape when brachiating is apparent.

The Quadratus Lumborum is quadrate but not rectangular, for its lateral border is oblique. It arises from the posterior two inches of the part of the inner lip of the iliac crest that bounds the iliac fossa, and from the ilio-lumbar ligament. It runs obliquely upwards and medially to be inserted into the medial two inches of the lower border of the last rib. Also, it gives slips to the tips of the lumbar transverse processes and it receives slips from them. Insignificant parts of these slips cover the tips of the 1st, 2nd, and 3rd transverse processes, where they project beyond the Psoas, and separate them from the kidney.

The Quadratus is enclosed within a sheath formed by the "anterior" and middle lamellae of the lumbar fascia. The thin "anterior lamella" is merely an areolar covering, slightly thickened above to form the *lateral arcuate ligament*—which gives origin to the diaphragm—and greatly thickened below where, under the title, *ilio-lumbar ligament*, it acts as a suspensory ligament for the 5th lumbar vertebra and prevents excessive rotation of the 5th vertebra at the lumbo-sacral joint.

The Transversus Abdominis helps to form a sheath for the Rectus Abdominis in front and for the deep muscles of the back behind (*fig. 199*). Near the lateral border of the Quadratus it becomes aponeurotic. This posterior aponeurosis divides into two layers: of these, the posterior passes to the tips of the

lumbar spines; the anterior (the middle lamella of the lumbar fascia) passes behind the Quadratus and attaches itself to the tips of the lumbar transverse processes by a series of converging fibers. It is also attached to the last rib above and to the iliac crest below.

Pectineus. It exemplifies the rule that fasciae do not cross exposed areas of bone but unite with them and, if strong, create lines or ridges. In accordance with this rule, it is found that (a) *Above and laterally*, the fascia iliaca is attached to the sharp, medial lip of the iliac crest. (b)

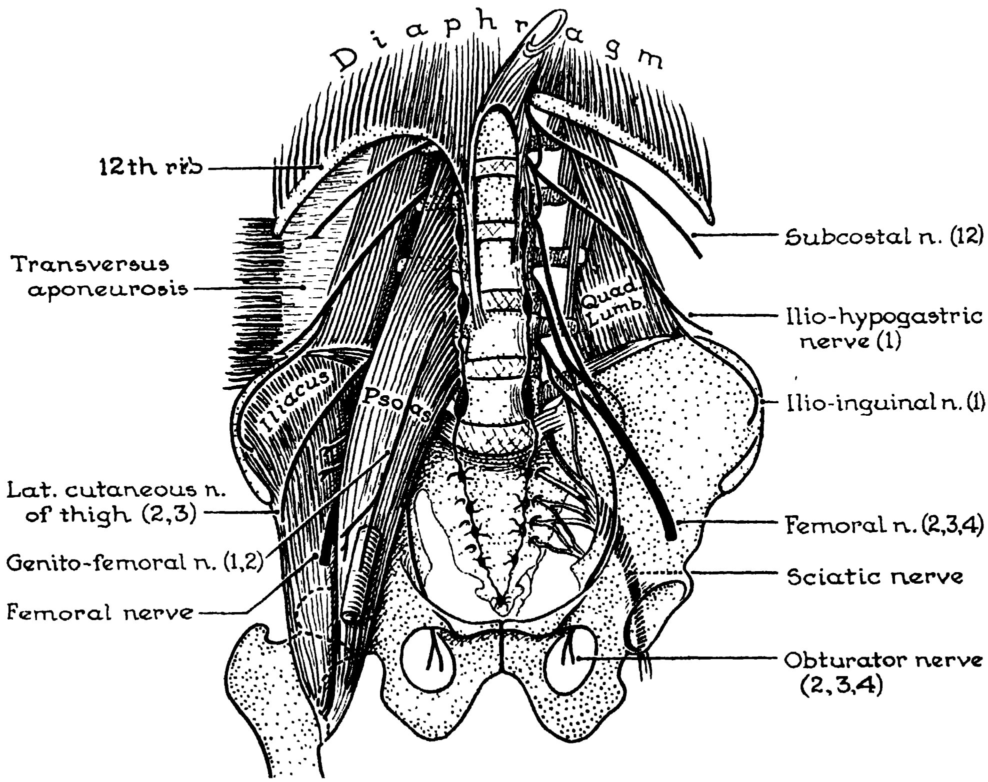


FIG. 301. The lumbar plexus and the muscles of the posterior abdominal wall.

The Intertransversarii (LATERALES) pass between adjacent borders of transverse processes. They are in series with the Levatores Costarum and are supplied by anterior nerve rami.

The Fascia Iliaca is a part of the general fascia that lines the muscles that enclose the abdominal cavity. This strong fascial sheet covers the Iliacus and the Psoas, and infero-medially it is continuous with the fascia that covers the

Medially, it is reinforced by the tendon of the Psoas Minor and it crosses the Psoas (and also the Pectineus) and gains attachment to the ilio-pectineal part of the pelvic brim and helps to render it sharp. More cranially, and still following the medial border of the Psoas, it crosses the ala of the sacrum obliquely and is there pierced by the ilio-lumbar vessels, the obturator nerve, and the descending half of the anterior ramus of nerve L. 4,

but, being weak, it makes no line on the ala. The anterior ramus of nerve L. 5 emerges from the intervertebral foramen below the origin of the Psoas and its fascia. The genito-femoral nerve pierces the Psoas fascia (sometimes as two roots). (c) *Below*, it is carried downwards in front of these 3 muscles—Iliacus, Psoas, and Pectineus—into the thigh. As the part covering the Iliacus is passing behind the inguinal ligament, it adheres to it and to the fascia transversalis; and in the thigh it lies deep to the fascia lata. But, the part covering the Psoas and Pectineus is separated from the inguinal ligament, fascia transversalis, and fascia lata by the femoral artery, femoral vein, and deep inguinal lymph vessels which here descend into the thigh wrapped around in extraperitoneal areolar tissue, called the femoral sheath (*fig. 376*). (d) The fascia iliaca is carried *upwards*, above the iliac crest, in front of the Psoas as the Psoas fascia.

The Psoas Fascia is thickened above to form the medial arcuate ligament (med. lumbo-costal arch), which gives origin to the diaphragm. Laterally, it blends with the Quadratus Lumborum fascia and is attached to the tips of the first three lumbar transverse processes, which project slightly beyond the Psoas (*fig. 301*). Medially, it is attached to the bodies of the lumbar vertebrae and to their discs. The attachment is, however, interrupted where the lumbar vessels and rami communicantes pass backwards on the sides of the bodies.

The Ilio-psoas, then, lies extrafascially in an osseo-fascial pocket; hence, the contractions of this muscle disturb to a minimum the viscera (e.g., appendix, caecum, and colon) that lie in front of it.

The Lumbar Nerves. The anterior and posterior roots of each of the five lumbar nerves unite in the intervertebral foramen, below the vertebra with which they correspond numerically, to form a lumbar nerve. Each mixed nerve so-formed at once divides into an anterior and a posterior ramus. The *posterior rami* are small. Each of them at once curves backwards, lateral to a superior articular process and medial to an Intertransverse muscle. The *anterior rami* are large, and they increase in size from the first to the fifth. Each of the five receives one or two gray rami communicantes from the sympathetic trunk; each of the upper 2 (or 3) sends a white ramus communicans to the sympathetic trunk; most of the lumbar nerves supply the Psoas, Quadratus Lumborum, and Intertransversarii. Each of the five continues downwards across the front of the root of the transverse process of the vertebra below, the fifth crossing the ala of the sacrum.

The Lumbar Plexus is formed by the anterior rami of the upper $3\frac{1}{2}$ lumbar nerves. The first ramus is joined by a branch of the twelfth thoracic ramus. The lower half of the fourth ramus joins the fifth ramus near the anterior border of the ala of the sacrum to form the *lumbo-sacral trunk*. The branches of the plexus encounter the Psoas and pass amongst its posterior fibers. With the exception of two branches, the *genito-femoral* and *obturator*, the plexus remains outside the fascial lining of the abdomen and pelvis. Its largest and most important branches are the *femoral* and *obturator nerves*, both of which spring from the segments L. 2, 3, and 4.

The Obturator Nerve courses to the upper part of the obturator foramen. It, therefore, appears from under cover of the medial border of the Psoas, where it pierces the psoas fascia. It then passes behind the junction of common and ex-

ternal iliac vessels and enters the true pelvis.

The Femoral Nerve courses to the lateral side of the femoral sheath and enters the thigh behind the inguinal ligament. It, therefore, appears at the lateral border of the Psoas, and runs downwards in the angle between the Psoas and Iliacus. Being extrafascial, it cannot enter the femoral sheath. It supplies the Iliacus.

It is of interest to observe that though the femoral nerve supplies the muscles on the front of the thigh, its three roots arise behind the three roots of the obturator nerve, which supplies the muscles on the medial aspect of the thigh. The explanation is that during development the limb undergoes medial rotation whereby the femoral nerve region, from being behind, is brought to the front, and the obturator nerve region is carried from the front to the medial side. The femoral nerve may be compared to a posterior division of the brachial plexus; the obturator nerve to an anterior.

In addition to the femoral nerve, four nerves appear at the lateral border of the Psoas. In ascending order they are: (a) *The Lateral (femoral) Cutaneous Nerve*, which arises from L. 2 and 3 either directly or else indirectly as a branch of the femoral nerve. It runs across the Iliacus and enters the thigh by passing behind the inguinal ligament anywhere between the anterior superior spine and the femoral nerve. (b) and (c) *The Ilio-inguinal* and *Ilio-hypogastric Nerves*, which arise either singly or together from L. 1, enter the abdomen behind the medial arcuate ligament, and cross in front of the Quadratus. The *ilio-inguinal nerve* is directed towards the anterior superior iliac spine. It pierces the Transversus about an inch behind the spine and the Internal Oblique about an inch in front of it, and then continues its course deep to the External Oblique aponeurosis less than a finger's breadth above the inguinal ligament. The *ilio-hypogastric nerve*, commonly containing fibers from Th. 12 as well as L. 1, follows a similar course at a higher level. It pierces the Transversus aponeurosis just beyond the Quadratus, and the Internal Oblique in front of the anterior superior spine. The lateral cutaneous branch of L. 1—known as the iliac branch of the ilio-hypogastric—arises from the ilio-hypogastric nerve, crosses the iliac crest beside the tubercle, and descends to the level of the greater trochanter of the femur. (d) *The Subcostal Nerve* (*anterior ramus of Th. 12*) which enters the abdomen behind the lateral arcuate ligament and, therefore, in front of the Quadratus Lumborum. It lies somewhat below the last rib, pierces the Transversus aponeurosis, and then runs between the Transversus and Obliquus Internus, which guide it ultimately to the Rectus sheath which it enters. Its lateral cutaneous branch crosses the iliac crest behind the anterior superior spine and descends to the level of the greater trochanter (*figs. 199, 201*).

The Genito-femoral Nerve (L. 1 and 2) comes to lie within the fascial lining of the abdomen and, to do so, pierces the Psoas and the psoas fascia. It divides at a very variable level into two branches, *femoral* and *genital*, which descend in front of the Psoas towards the midinguinal point. The *femoral branch* (lumbo-inguinal n.) is the cutaneous nerve of the femoral triangle. To reach the triangle it requires to pierce the fascia a second time. It does so in several branches which run lateral to the femoral artery, below the inguinal ligament, and through the fascia lata. The *genital branch* (ext. spermatic n.) supplies the

cremaster muscle and traverses the inguinal canal to end in the skin of the scrotum. In its course it passes in front of the end of the external iliac artery and pierces the coverings of the spermatic cord, one by one.

Variations. A considerable and variable interchange of fibers takes place in the abdominal wall between the ilio-hypogastric, ilio-inguinal, lateral femoral cutaneous, and genito-femoral nerves, in consequence of which the territory each supplies is variable.

An *Accessory Obturator Nerve* commonly arises from L. 3 and 4. It is a small nerve which, when present, adheres to the psoas fascia along the medial border of the Psoas. It crosses the superior ramus of the pubis and sends branches to the Pectineus and hip joint.

THE DIAPHRAGM

The diaphragm (Gk. dia = through, across; phragma = a partition) is the dome-shaped musculo-aponeurotic partition between the thorax and the abdomen. It has a rounded cupola on each side below the lungs, and a depressed median portion on which the heart lies. The median portion rises to the level of the xiphi-sternal joint which corresponds behind to the body of the 9th Th. vertebra or 8th spine. The right cupola rises to the 5th rib half-an-inch below the right nipple; the left cupola rises to the 5th interspace, an inch below the left nipple. These correspond on the posterior surface of the body to points $\frac{1}{2}''$ and $1''$ below the inferior angles of the scapulae.

Attachments and Marginal Gaps. The diaphragm is attached on each side by fleshy digitations to the back of the xiphoid process, to the inner surfaces of the 7th to 12th costal cartilages, and to the vertebral column. The costal slips interdigitate with slips of the Transversus Abdominis. Of the vertebral attachments or *crura*, the more powerful right crus is attached to the bodies of the upper three lumbar vertebrae; the left to the bodies of the upper two.

Anteriorly, in the median plane, there is a slight gap between the right and left xiphoid slips.

Posteriorly, in the median plane, there is a large gap between the two crura; through this the aorta passes. The medial parts of the crura are fibrous, and they join in front of the aorta immediately above the coeliac artery to form the *median arcuate ligament.*

Anteriorly, on each side, between the xiphoid slip and the slip from the 7th c. cartilage, the superior epigastric vessels pass into the rectus sheath.

Posteriorly, on each side, between the crus and the slip from the 12th rib, the pleural and peritoneal cavities are continuous with each other in prenatal life until crural fibers migrate laterally across the space towards the 12th rib, and as a rule succeed in reaching it, thereby closing the space and separating the two cavities (*fig. 302*). Sometimes they fail; a triangular gap, the *vertebro-costal trigone* (lumbo-costal trigone), is the result. The fibers closing the space find attachment to the fascia covering the Psoas and Quadratus Lumborum, which in response becomes thickened and strengthened to form the *medial* and *lateral arcuate ligaments* (lumbo-costal arches). Of these, the medial lig. bridges the Psoas and extends from the lateral border of the crus to the transverse process of the 1st lumbar vertebra; the lateral lig. bridges the Quadratus and extends from the latter point to the middle of the 12th rib. In consequence, the upper ends of the Psoas and Quadratus lie within the thorax.

In cases where the pleural and peritoneal

cavities remain in open communication through the vertebro-costal trigone, some of the abdominal contents may come to occupy the pleural cavity; that is to say, a *congenital diaphragmatic hernia* results. But even when the diaphragm fails to close the space, an areolar membrane usually does so. The kidney overlies the trigone and an easy path exists for infec-

larges during inspiration due to the pull of the surrounding fleshy fibers, and its contents are hurried on to the heart.*

The Oesophagus pierces the decussating fibers of the right crus at the level of the 10th vertebra. These fibers appear to act as a sphincter for the cardiac end of the stomach and prevent its contents from returning to the oesophagus.

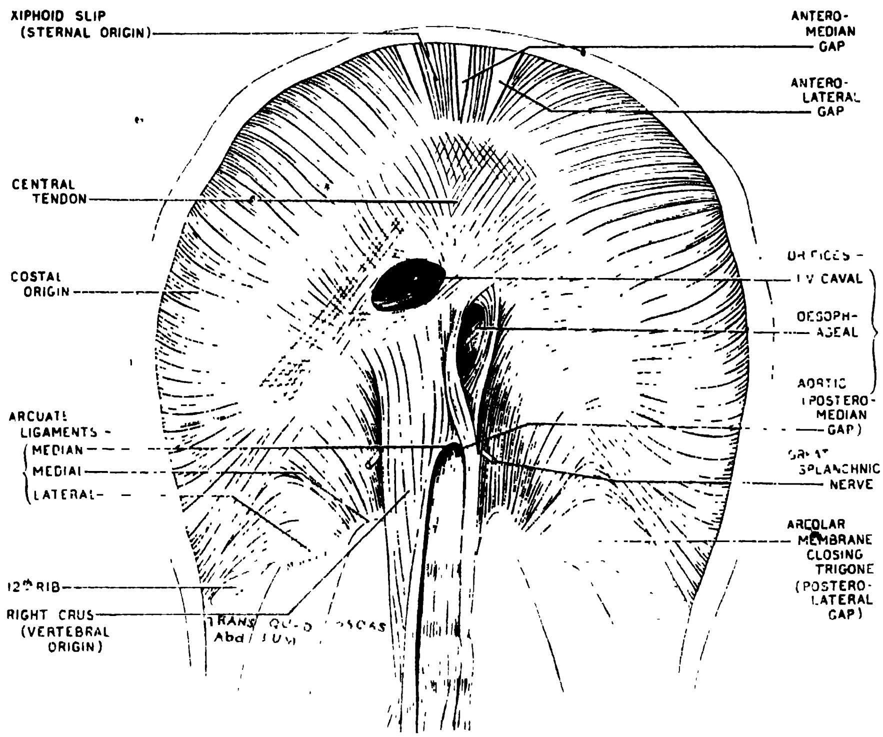


FIG. 302. The abdominal surface of the diaphragm.

tion to spread from the kidney region to the pleural cavity, and vice versa.

Structure. The central part of the diaphragm is called the *central tendon*. It is composed of decussating and interwoven tendinous fibers, and it has the shape of a trefoil or clover leaf. The peripheral fleshy fibers converge on it.

Structures piercing. *The I. V. Cava* pierces the central tendon at the level of the 8th Th. vertebra. Its orifice en-

The Aorta does not pierce the diaphragm but passes behind the median arcuate ligament at the level of the 12th vertebra. It is not affected by the contraction of the diaphragm.

These vertebral levels, then, are 8, 10,

* In some animals there is a certain degree of constriction of the i. v. cava during strong contraction of the diaphragm, as revealed by X-ray following injections of thorotrast; and, it is not agreed by all that in man the i. v. caval opening in the diaphragm does enlarge during inspiration. (Franklin.)

12. The aortic orifice is in the median plane; the caval orifice is an inch to the right; the oesophageal orifice is an inch or less to the left.

OTHER STRUCTURES PIERCING

Through the caval opening pass some branches of the *right phrenic nerve.* The left phrenic and other branches of the right phrenic pierce the diaphragm independently to spread out on its abdominal surface.

Through the oesophageal orifice pass the *gastric nerves* (the anterior in front of the oesophagus, the posterior behind it) and the *oesophageal branches of the left gastric artery and vein.* The vein is of special importance, because, anastomosing, as it does, with oesophageal branches of the azygos veins, it connects the portal and systemic venous systems. (p. 252).

Through the aortic orifice passes the *thoracic duct* [also a vein connecting the right ascending lumbar vein to the azygos system].

The phrenic and gastric nerves are not the only nerves to pass through the diaphragm, for on each side the 3 *splanchnic nerves* (great, small, and smallest) pierce the crura to end in the coeliac (and aortico-renal) ganglia.

Nerve and Blood Supply (*fig. 303*). The diaphragm is supplied by (a) the phrenic nerve (C. 3, 4, and 5) which is both motor and sensory, (b) the lower intercostal nerves, which are sensory to the peripheral parts, and (c) branches from the coeliac ganglion, which are probably concerned with the tone of the diaphragm.

The greater part of the diaphragm developed in the neck, but descended before the expanding lungs, drawing the phrenic nerves after it. The phrenic nerve is the only motor nerve to the diaphragm. If cut (in the dog) the diaphragm atrophies and becomes fibrous up to the median plane. Cutting the different roots of the phrenic nerve (in goats) reveals the fact that the upper root supplies the anterior part of the diaphragm, the middle the intermediate part, and the lower the hinder part.

The pericardiaco-phrenic, (inferior) phrenic, musculo-phrenic, and intercostal arteries supply the diaphragm.

Relations. *The abdominal relations* are: the liver, stomach, spleen, coeliac

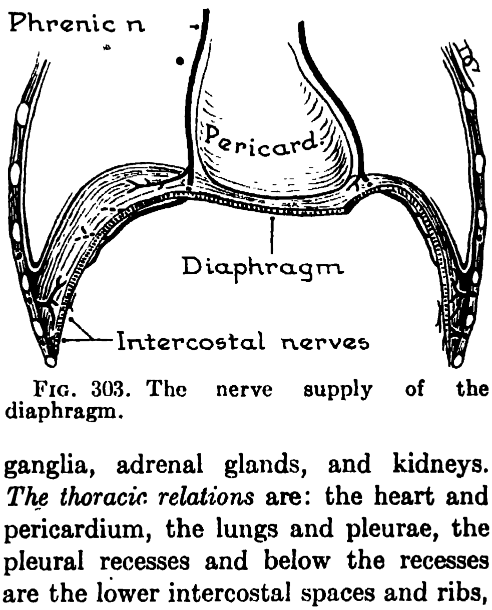


FIG. 303. The nerve supply of the diaphragm.

ganglia, adrenal glands, and kidneys. *The thoracic relations* are: the heart and pericardium, the lungs and pleurae, the pleural recesses and below the recesses are the lower intercostal spaces and ribs, the thoracic aorta and the oesophagus (*figs. 216, 534*).

Development. The fully formed diaphragm is derived from a mesodermal partition of composite origin (*fig. 304*). The antero-median part arose from the septum transversum; the postero-median part arose from the primitive dorsal mesentery; the lateral parts were, so to speak, dissected off the body wall by the developing lungs; the gap, the *pleuro-peritoneal canal,* on each side between the postero-median and the lateral part

is closed by a membrane, the *pleuroperitoneal membrane.* In the young embryo the hinder part of this composite partition lies at the level of vertebra C. 2; but it has a long descent to make, for ultimately, as the crura of the diaphragm, it gains attachment to vertebrae L. 2 and 3. On passing vertebrae C. 3, 4, and 5, portions of the myotomes of these segments, supplied by the phrenic nerve, extend into it and pervade it, thereby forming the muscular diaphragm.

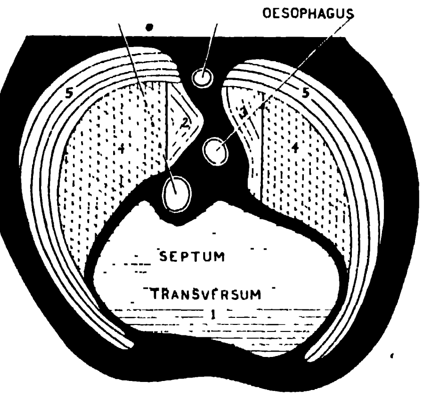


FIG. 301. The elements from which the diaphragm is developed. 1 = septum transversum; 2, 3 = dorsal mesentery; 4 = pleuroperitoneal membrane; 5 = body wall (After Broman.)

THE SEPTUM TRANSVERSUM is the thick mesodermal mass that surrounds the vitelline veins (also the common cardinal veins) prior to their entering the sinus venosus of the heart. At a certain period this septum projects horizontally backwards from the anterior body wall to meet the dorsal mesentery at the level where the duct system of the liver (of endodermal origin) buds from the duodenum. Ultimately, the septum separates into three layers: (1) the upper layer forms part of the pericardium; (2) the intermediate layer forms part of the diaphragm; (3) the lower layer forms the connective tissue stroma of the liver.

The enlarging peritoneal cavity, by extending into the septum transversum between layers 2 and 3, "dissects" the liver from the diaphragm—but not entirely. Thus, "dissection" is practically complete on the *left side*, except for the left triangular ligament; in the *median plane*, except for the falciform ligament; and on the *right side*, except for the bare area bounded by the coronary ligament—here liver and diaphragm remain loosely connected. By this provision, during respiration, the contracting diaphragm can glide unhampered on the liver.

THE ABDOMINAL LYMPHATICS

Lymph capillaries, lymph vessels, and lymph glands occupy areolar and fascial planes, e.g., the deep fascia of the skin, submucous and subserous coats of viscera. Lymph capillaries form networks which drain by the nearest issuing lymph vessels. Retrograde flow is prohibited by numerous valves. If one group of vessels is obstructed, the lymph escapes into the next nearest issuing vessels, like water from a marsh. In two parts of the body, hollow, fingerlike projections, blind at one end, are erected on the network. They project into (a) the papillae of the skin and (b) the villi of the intestines. After a meal the intestinal lymph vessels contain emulsified fat; and, since this is white like milk, the vessels are called *lacteals.*

The external and common iliac chains of glands (*fig. 372*) continue upwards along the sides of the aorta and around it as the *right* and *left lateral aortic* or *lumbar chains of glands.* They open by means of a *right* and a *left lumbar lymph trunk* into a tubular sac, called the *cisterna* (receptaculum) *chyli.* The inf. vena cava runs through the right chain making it less accessible than the left.

These chains receive (1) lymph already filtered by glands and coming from

the lower limbs, lower part of the anterior abdominal wall, external genitals, perineum, and pelvis; (2) lymph vessels that follow the lumbar vessels and drain the posterior abdominal wall; (3) the vessels from the three paired glands—adrenal, kidney, and testis (the ovary, upper part of the uterus, and the uterine tube in the female)—and (4) the part of the gastro-intestinal tract supplied by the inferior mesenteric artery drains into the left aortic chain. (The parts supplied by the coeliac and superior mesenteric arteries drain by means of a gastro-intestinal trunk into the cisterna chyli.)

The cisterna chyli will be described now and the drainage of the gastro-intestinal canal and of the three unpaired glands (liver, pancreas, and spleen) will be considered

The Cisterna Chyli resembles a two-inch segment of a vein, but it is white. Its diameter is less than that of a lead pencil, but it may be irregularly dilated. It lies between the aorta and the right crus of the diaphragm but the vena azygos, when present, separates it from the crus. It receives five or more trunks, namely, the *right* and *left lumbar trunks*, the *gastro-intestinal trunk*, and a *pair of vessels* that descend from the lower intercostal spaces. On passing through the aortic opening it becomes the thoracic duct.

The Intestine. The glands of the *large intestine* are numerous and are roughly arranged in three groups: (1) *paracolic glands* on the marginal artery close to the gut wall, (2) *intermediate glands* on the stems of the colic arteries, and (3) *main glands* near the roots of the colic arteries, beside the aorta. The lymph vessels from the intestine follow the blood vessels fairly closely and each vessel is interrupted by one or more groups of glands. The lymph vessels from the segment of the large gut between the appendix and the left end of the transverse colon follow the branches of the superior mesenteric artery and join to form the *intestinal trunk*. Those from the left colic flexure and remainder of the large gut follow the branches of the inferior mesenteric artery and end amongst the glands of the left aortic chain. There may be an appendicular gland in the mesentery of the appendix; there are many glands clustered in the ileo-colic angle; the vessels from the transverse colon have the longest distance to travel; those at the left colic flexure communicate with the splenic glands, travelling probably along the route of the occasional artery described on page 263.

The Small Intestine is drained through numerous glands divisible like those of the large intestine into three groups. Ultimately a channel, the *intestinal trunk*, emerges and, by joining the *gastric trunk*, forms the *gastro-intestinal trunk* which opens into the cisterna chyli.

The Stomach and the Three Unpaired Glands (Liver, Pancreas, and Spleen). LYMPH GLANDS. Along the upper border of the pancreas there are *middle, right, and left suprapancreatic groups* of glands related to the coeliac artery and to its hepatic and splenic branches. A *subpyloric* group is applied to the front of the head of the pancreas below the pylorus; a *left gastric chain* lies on the course of the left gastric artery; a *biliary chain* extends along the bile passages from the porta hepatis above, through the lesser omentum, and behind the first part of the duodenum and head of the pancreas, to the second part of the duodenum below. And, there is a *main group of colic glands* at the root of the mesentery.

THE STOMACH. The lymph vessels from the part of the stomach that lies to

the left of a vertical line dropped through the oesophagus pass with the left gastro-epiploic and short gastric arteries through the gastro-splenic and the lieno-renal ligaments to the suprapancreatic glands; some, however, pass to a necklace of glands placed around the oesophageal opening. Of the lymph vessels to the right of this vertical line, (a) the upper ones run to the left to glands placed on the left gastric artery at the left end of the lesser curvature of the stomach and are there in part intercepted, but some vessels pass by these glands to more distant ones on the stem of the left gastric artery, and so to suprapancreatic glands. (b) The lower vessels run to the right to glands placed on the right gastro-epiploic artery at the right end of the greater curvature, thence to the subpyloric group, from which they are dispersed to suprapancreatic glands and to the main group of superior mesenteric glands.

(c) At the extreme pyloric end of the lesser curvature several lymph vessels follow the right gastric artery.

The lymph plexuses of the stomach communicate with those of the oesophagus; but only feebly, if at all, with those of the duodenum. This is due to: the connective tissue septum in the submucous coat at the pyloric sphincter, to discontinuity of the circular muscle fibers, and to indipping of the longitudinal muscle fibers.

THE LIVER. Lymph vessels from the upper surface of the liver pass through the falciform ligament to retrosternal glands, which lie on the diaphragm and discharge into the internal mammary chain; some from the interior, following the hepatic veins, pass with i. v. cava through the diaphragm to diaphragmatic glands, thence to the thoracic duct; others, following the branches of the portal vein, emerge at the porta and travel down the biliary chain to be distributed to the various pancreatic glands. There is an intercepting gland, the *cystic gland*, at the neck of the gall-bladder and there are others "hepatic glands" in the porta hepatis.

THE PANCREAS drains into adjacent glands.

THE SPLEEN drains into splenic glands situated where the tip of the pancreas abuts against the spleen.

SECTION IV

THE PERINEUM AND PELVIS

CHAPTER 11

THE PERINEUM

The perineum is the region round about the outflow from the rectum and bladder It is a diamond-shaped space at whose angles are the inferior pubic (arcuate) ligament, the tip of the coccyx, and the ischial tuberosities. The pubic arch and the sacro-tuberous ligaments form its sides (*fig. 305*). The sacro-tuberous ligament, however, is hidden by the border of the Gluteus Maximus. The ischial tuberosities bear the weight of the body when sitting; so, they are covered by a thick mass of tough, stringy, fibrous tissue in which a bursa may be buried.

The anterior half of this diamond is called the *urogenital triangle;* the posterior half is the *anal triangle.*

Developmental Considerations. In the embryo the endodermal alimentary canal ends in a blind receptacle, the *cloaca,* shaped somewhat like a coffee pot, the spout being the *allantoic diverticulum,* definitively the *urachus.* The *mesonephric duct* (definitively the *vas deferens* in the male) grows caudally and opens into the anterior part of the cloaca. The *ureter* develops as an outgrowth from the mesonephric duct, and the two have for a period a common terminal duct (*figs. 306, 307*). This common duct is absorbed subsequently into the posterior wall of the bladder and prostatic urethra with the result that the ureter and vas deferens come to have independent openings.

In reptiles and birds the cloaca opens on to the skin surface through an orifice, guarded by a sphincter of striated muscle, the *cloacal sphincter,* which is derived from cutaneous tissue. In mammals, including man, a septum of mesoderm, the *uro-rectal septum,* divides the cloaca into (a) an anterior or uro-genital part, and (b) a posterior or intestinal part.

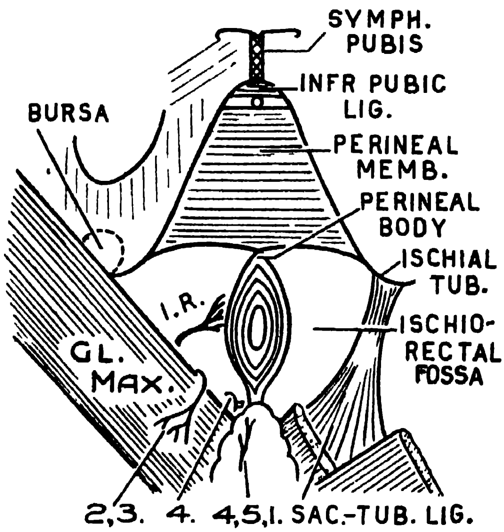


FIG 305 Boundaries and subdivisions of the perineum

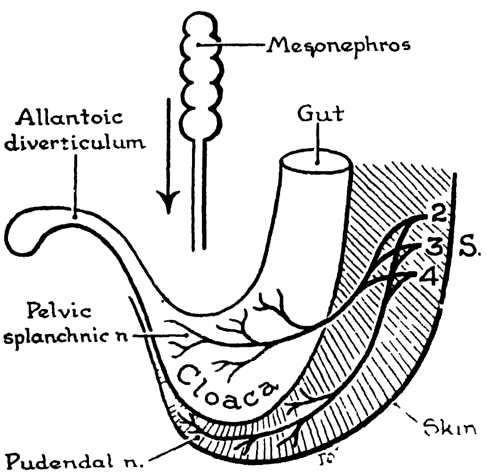
The cloacal sphincter also divides into anterior and posterior parts: the posterior part becomes the Sphincter Ani Externus, the anterior part becomes the Transversus Perinei Superficialis, Bulbospongiosus, Ischio-cavernosus, and urogenital diaphragm.

From these considerations you will understand why on one nerve, the *puden-*

dal n., which is a mixed nerve, falls the onus of supplying all the muscles into which the cloacal sphincter divides, as well as the skin of the region round about it; and why its companion artery, the *pudendal a.*, nourishes the entire territory; also why the bladder and rectum have a common nerve supply (the pelvic splanchnic n. and the hypogastric plexus).

Definitions. It is well to define now the following terms:

1. The "*Urogenital Diaphragm*" (*fig. 308*) is a thin sheet of striated muscle which stretches between the two sides



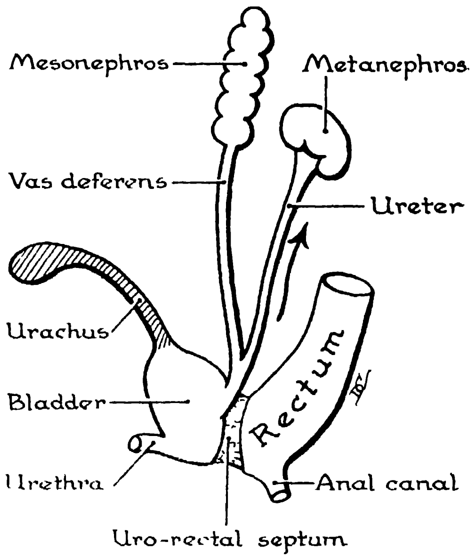
EARLY

FIG. 306. The cloaca and its nerve supply.

of the pubic arch. Its most anterior fibers and its most posterior fibers (Transversus Perinei Profundus) run transversely. Its middle fibers (Sphincter Urethrae) in part encircle the urethra, and in part decussate and embrace it, much as the fibers of the crura of the "thoraco-abdominal" diaphragm embrace the oesophagus. Like other muscles, the urogenital diaphragm is enveloped in areolar tissue; and because the diaphragm is flat, its envelope forms two sheets, "the inferior and superior fasciae of the urogenital diaphragm".

The inferior sheet of fascia is called the *perineal membrane*.

2. *The Superficial Perineal Fascia of Colles* is the fascia of Scarpa continued into the perineum. Its attachments are to: the fascia lata, the pubic arch, and the base of the perineal membrane (*fig 308*). In front it is prolonged over the penis and scrotum and so forms a covering for the testes and spermatic cords. From this it follows that its line of attachment to the fascia lata must pass



LATER

FIG. 307. The connections and subdivisions of the cloaca.

lateral to the superficial inguinal ring (*fig. 196*).

3. *The Superficial Perineal Pouch* is the space between the superficial perineal fascia and the perineal membrane. Should the urethra rupture into this space, the attachments of Colles' fascia will determine the direction of flow of the extravasated urine—not to the anal triangle nor the thigh, but into the scrotum, around the penis, and upwards into the abdominal wall.

4. *The Deep Perineal Pouch* is the

space enclosed by "the superior and inferior fasciae of the urogenital diaphragm". Among its contents are the membranous urethra and the Sphincter Urethrae.

5. *The Perineal Body* is a small fibrous area at the central point of the perineum. The base of the perineal membrane and several muscles are attached to it. The muscles are the Sphincter Ani Externus, Transversus Perinei Superficialis, Bulbospongiosus, and in part the Levator Ani.

and join the opposite Superficial Transverse Perineal muscle. Above, it is not always sharply defined from the Levator Ani; inferiorly, many branches of the inferior rectal (haemorrhoidal) vessels and nerve pass between the superficial and deep parts. (*Fig. 313*).

The Ischio-rectal Fossae are the fascial-lined, wedge-shaped spaces, one on each side of the anal canal and rectum. Filled with fat, which is fluid at body temperature, they allow the rectum to become distended and to empty. Each

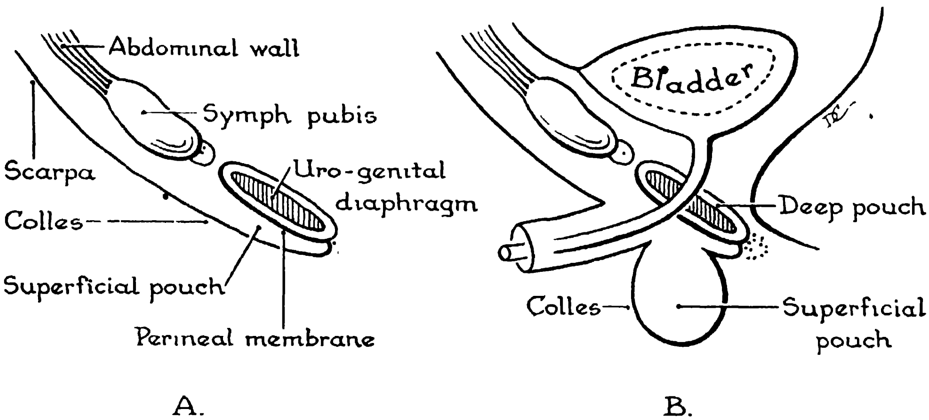


FIG. 308. To explain the urogenital diaphragm and the perineal pouches (schematic).

The Anal Triangle

The Sphincter Ani Externus (Anus, L. = a ring) is a sphincter of voluntary muscle, 1″ deep, placed around the anal canal. It has three parts—subcutaneous, superficial, and deep. *The Subcutaneous Part* is slender and encircles the anal orifice. *The Superficial Part* is elliptical and extends from the tip of the coccyx and ano-coccygeal raphé (i.e., a fibrous band between anus and coccyx) to the perineal body. It moors the circular anus to the median plane, but offers it little support fore and aft. *The Deep Part* encircles the anal canal like a collar; in front, however, some fibers decussate

fossa is bounded laterally by the ischium, from which the Obturator Internus arises (*fig. 309*); medially, by the rectum and anal canal, to which the Levator Ani and External Sphincter are applied; posteriorly, by the sacro-tuberous ligament and the overlying Gluteus Maximus; anteriorly, by the base of the "urogenital diaphragm and its fasciae". A finger tip may, however, be passed forwards above the base of the u.g. diaphragm and lateral to the prostate into a short cul-de-sac until arrested by the blending of the superior fascia of the u.g. diaphragm, the fascia covering Levator Ani, and the fascia covering the pros-

tate. The fascia covering the Obturator Internus is fairly strong and it extends upwards beyond the fossa, reaching posteriorly to the pelvic brim (*fig. 330*). The fascia covering the Levator Ani is weak. The apex of this fascial-lined, wedge-shaped fossa is formed by the Levator Ani arising from the Obturator Internus fascia about 2½ inches above the ischial tuberosity.

The fascial linings of the right and left fossae blend posteriorly, between rectum and coccyx, to form a weak, median, areolar partition whose lower free border is the anococcygeal raphé.

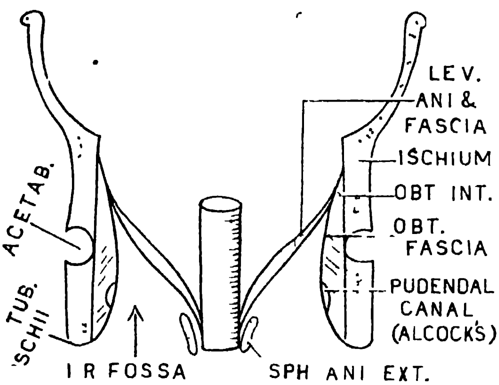


FIG. 309 The pelvis in coronal section to show the ischio-rectal fossa (schematic)

The internal pudendal vessels and nerve (pudere, L. = to be ashamed, cf. impudent) run forwards in an areolar sheath, the *pudendal canal* of Alcock, which is adherent to the lateral surface of the Obturator Internus fascia, 1 inch above the tuberosity. Far back they give off the inferior rectal or hemorrhoidal vessels and nerve, which become more and more superficial as they pass forwards and medially through the ischio-rectal fossa towards the surface to supply the External Sphincter and the skin around the anus.

Two other cutaneous nerves, the *perforating cutaneous* branch of the 2nd and 3rd sacral and the *perineal branch* of the 4th sacral are shown in figure 305.

The Urogenital Triangle in the Male comprises the superficial and the deep perineal pouch. When the superficial perineal fascia of Colles, which is somewhat laminated, is incised longitudinally on each side of the median line, the **Superficial Perineal Pouch** of Colles is opened. It is seen to be divided imperfectly into a right and a left side by an areolar septum, and, it is continued, deep to the fascia of Scarpa, into the ant. abdominal wall (*fig. 194*)

The *two posterior scrotal branches of the perineal nerve* pierce the base of the perineal membrane, and the *perineal branch of the posterior cutaneous nerve of the thigh* pierces the attachment of Colles' fascia to the pubic arch; thereafter these 3 sensory nerves can be followed forwards on to the scrotum accompanied by the *posterior scrotal arteries*. A small artery, called the *transverse perineal a.*, runs along the base of the pouch to meet its fellow.

THE CONTENTS OF THE SUPERFICIAL POUCH ARE:

(a) 3 superficial nerves, just described,
(b) 3 superficial arteries, just described,
(c) 3 superficial muscles (page 312), all of which are paired, and
(d) The root of the penis.

The Penis (penis, L. = a tail) is composed of three fibro-elastic cylinders, the right and left *corpora cavernosa penis* and the *corpus spongiosum penis* (urethrae) (*fig. 310*), which are filled with erectile tissue and are enveloped in fasciae and skin. The corpora cavernosa penis fuse with each other in the median plane, except behind where, as two diverging *crura*, they separate to find attachment on each side to an inch of the pubic arch. They form an elastic support or skeleton

for the corpus spongiosum penis which is traversed by the urethra, and which lies below and between them. The corpus spongiosum can easily be dissected free from the corpora cavernosa. It is then

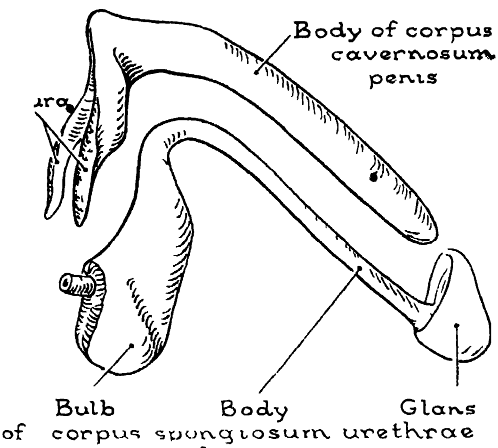


FIG. 310 The parts of the penis

seen to be swollen in front where, as the *glans penis*, it fits on to the blunt end of the united corpora cavernosa penis, and swollen behind where, as the ***bulbus penis***, it is fixed to the perineal membrane.

The perineal membrane (inf. fascia of the u-g. diaphragm) serves to moor the bulb of the penis to the pubic arch and, accordingly, it is stronger than the superior fascia of the diaphragm.

COVERINGS The skin of the abdominal wall and scrotum and the two layers of the superficial fascia (Camper and Scarpa) are prolonged over the penis as a series of very loosely connected envelopes which end as the *foreskin* or *prepuce*. The skin is devoid of hairs and the fascia of fat. Deep to these, a closed tube of denser and more tightly fitting fascia, the *fascia penis*, envelopes the body of the penis from the corona of the glans to the root of the penis. This fascia is adherent on each side in the groove between the c cavernosum and c spongiosum *The Suspensory Ligament of the Penis* is a thick, triangular fibro-elastic band. Above, it is fixed to the lower part of the linea alba and upper part of the symphysis pubis; below, it splits to form a sling for the penis at the junction of its fixed and mobile parts (i.e., where the organ is bent) and here it blends with the fascia penis

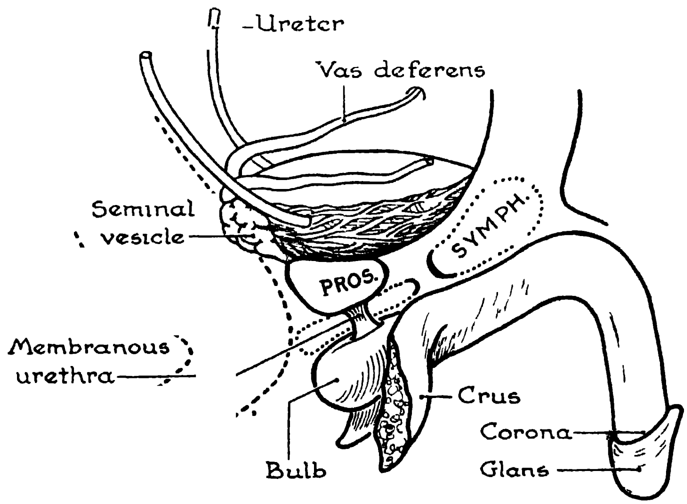


FIG 311 The lower parts of the genital and urinary tracts and their relations

VESSELS AND NERVES. The (deep) dorsal nerves, arteries, vein, and lymph vessels run along the dorsum penis deep to the fascia penis and end, or begin, in the glans. Encircling branches of the vein (*fig. 312*) drain the c. cavernosa and c. spongiosum; encircling lymph vessels drain the spongy or penile urethra; encircling arteries send twigs to the c. cavernosa and c. spongiosum. The *deep dorsal vein* passes between the inferior pubic ligament and the u.g. diaphragm to end in the prostatic plexus of veins. The *lymph vessels* end in the deep inguinal glands; others pass through the femoral and inguinal canals to the external iliac glands. *The erectile tissue* is, therefore, supplied by 3 paired arteries: the artery to the bulb, the artery to the crus (deep artery), and the dorsal artery The last named artery sends encircling twigs to assist the former 2 arteries. Its vaso-motor nerves are derived from the pelvic splanchnics (*p. 367 and fig. 48*).

The coverings of the penis (skin and fasciae) are supplied by the dorsal aa. of the penis and by the external pudendal branches of the femoral a. They are drained by the superficial dorsal vein, which begins in the prepuce where it anastomoses with branches of the deep dorsal vein. The superficial dorsal vein ends by dividing into right and left branches which pass via the external pudendal veins to the long saphenous veins. The lymph vessels of the coverings anastomose in the prepuce with branches of the deep vessels and end in the superficial inguinal glands. The nerves are branches of the dorsal nerve. The genital branch of the genito-femoral n. and the ilio-inguinal n. supply the parts near the pubis.

The Superficial Perineal Muscles. On each side 3 muscles lie in the superficial perineal pouch. They are the slender *Transversus Perinei Superficialis*, which lies at the base of the pouch and extends from the ischial tuberosity to the perineal body; the *Ischio-cavernosus*, which is applied to the crus; and the *Bulbo-spongiosus*, a bilateral structure, which arises from the perineal body and a median raphé below the corpus spongiosum. The most posterior fibers of the Bulbo-spongiosus pass to the perineal membrane; the intermediate fibers of the two sides meet on the dorsum of the corpus spongiosum; and the most anterior fibers meet on the dorsum of the penis, where they blend with the fascia penis. The Bulbo-spongiosus is a sphinc-

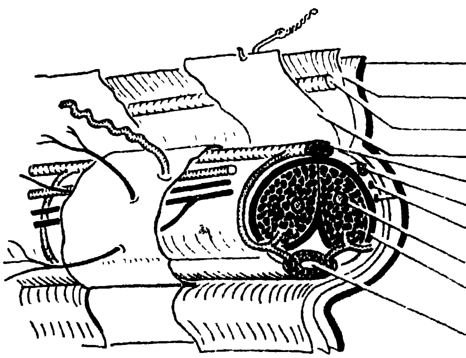


FIG. 312. The penis on cross section, its coverings and its vessels

ter which empties the bulb and the hinder part of the spongy urethra.

When the 3 muscles are gently separated from each other, a triangular area of perineal membrane is brought into view.

The Deep Perineal Pouch is the space enclosed by the upper and lower fasciae of the urogenital diaphragm. Within it lie (1) the deep perineal muscles which form the diaphragm, viz., Transversus Perinei Profundus and Sphincter Urethrae, (2) the membranous urethra which transverses it, (3) two small glands, the *bulbo-urethral glands* of Cowper. Each gland, the size of a pea, lies deep to the diaphragm, and its long duct travels in the wall of the urethra for an inch before opening into the spongy urethra (*figs. 316, 324*), and (4) vessels and nerves to be described now.

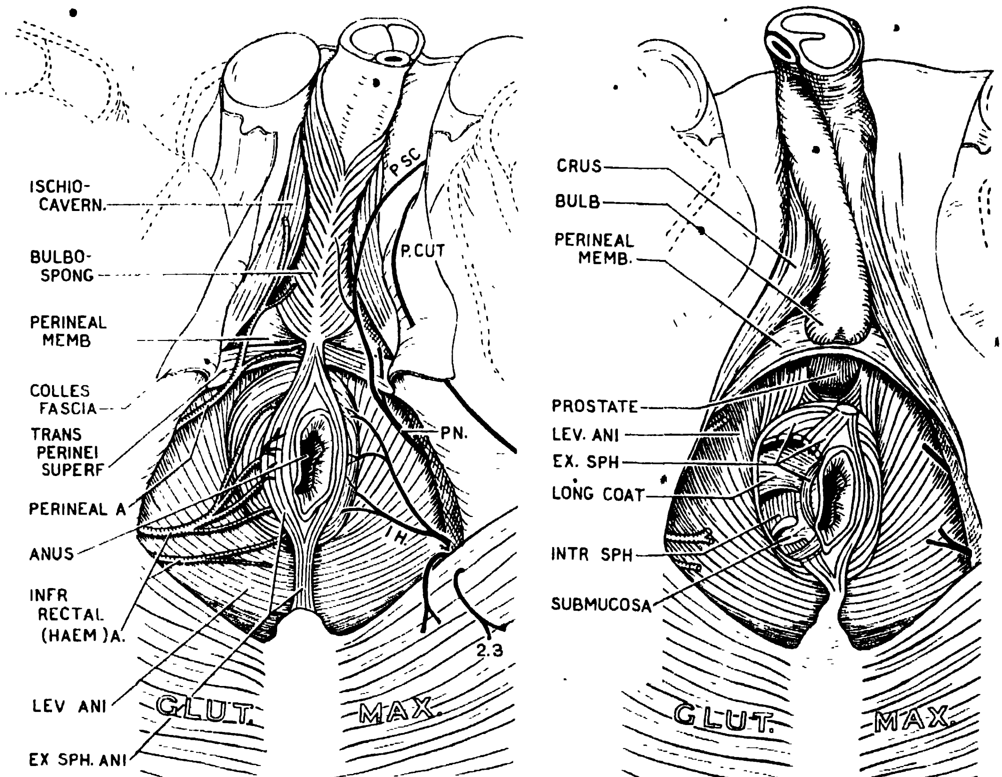


FIG. 313. Left: Superficial dissection of the male perineum. (By Dr. H. C. Hair.) Right: Exposure of the prostate gland; dissection of the anal canal. (By Dr. V. P. Collins.) I.H. = inferior haemorrhoidal n.; P.N. = perineal n.; P.Sc. = posterior scrotal n.; P. cut = perineal branch of posterior cutaneous n. of thigh.

The Internal Pudendal Vessels and Nerve. The artery, which is a branch of the internal iliac artery, and the nerve, which arises from sacral segments 2, 3, and 4, together leave the pelvis through the greater sciatic foramen to enter the gluteal region (*fig. 314*). This they leave immediately by crossing the ischial spine and passing through the lesser sciatic foramen to enter the pudendal canal.

Thus do they arrive in the perineum. They have 3 territories to supply (1) the anal triangle, (2) the urogenital triangle and scrotum, (labium majus in the female), and (3) the dorsum penis (dorsum clitoridis in the female).

The artery and nerve travel together, but, whereas the artery divides far forwards into 2 terminal branches, the nerve ends far back by dividing into 3 terminal branches. This complicates somewhat ternal Sphincter Ani and the skin about the anus.

(2) *The perineal nerve*, also a mixed nerve, runs below the artery through the pudendal canal to the base of the perineal membrane where its two cutaneous branches, the *posterior scrotal nerves*, enter the superficial perineal pouch, supply it, and continue forwards to the scrotum; while its motor branch, the *deep perineal nerve*, enters the deep perineal pouch

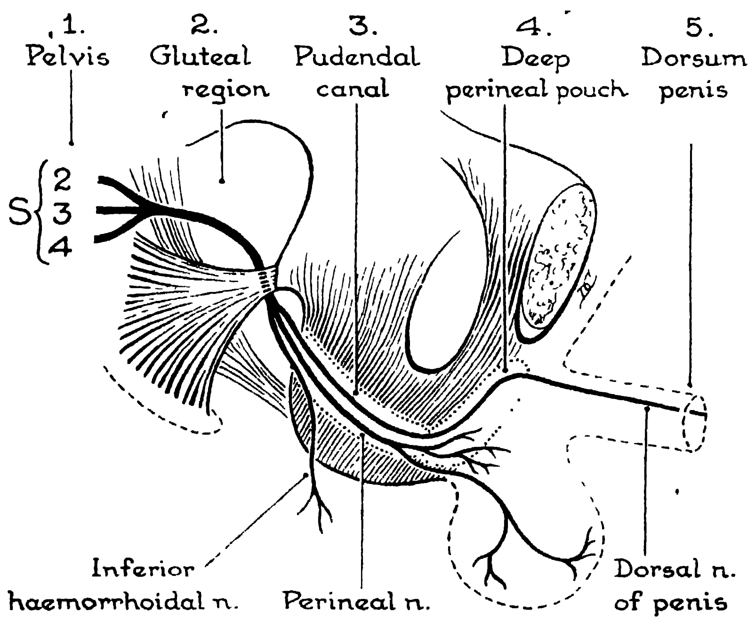


FIG. 314. The course of the pudendal nerve: Its three divisions and five territories.

the nomenclature and makes description cumbersome; figures 315 and 314 are explanatory. Follow the nerve first.

THE (INTERNAL) PUDENDAL NERVE divides far back in the pudendal canal into 3 terminal divisions for the supply of the 3 territories.

(1) *The inferior hemorrhoidal nerve* is a mixed nerve whose branches become more and more superficial as they are traced forwards and medially, through the ischio-rectal fossa, to supply the External Sphincter Ani and the skin about the anus.

from which it innervates the different parts of the diaphragm and the 3 superficial muscles, and sends twigs to the External Sphincter Ani and to the Levator Ani.

(3) *The dorsal nerve of the penis* is a sensory nerve that follows the dorsal artery through the pudendal canal, through the deep perineal pouch, and along the dorsum of the penis, where it lies deep to the fascia penis. It supplies the glans, the prepuce, and the skin of the penis.

THE INTERNAL PUDENAL ARTERY travels through the anal triangle in Alcock's pudendal canal, which extends from the lesser sciatic foramen to the deep perineal pouch. It then travels through the urogenital triangle in the deep perineal pouch, where it lies under shelter of the pubic arch deep to the u.g. diaphragm. Finally, as the *dorsal artery of the penis,* it pierces the perineal membrane half-an-inch from the symphysis pubis and continues, deep to the fascia of the penis, as far as the glans in which it ends. On the dorsum of the penis, it lies, as arteries so often do, between its companion vein and nerve.

Its named branches are: (1) *The inferior rectal* or *hemorrhoidal a* which supplies the anal triangle, (2) *The perineal a.* which at the base of the perineal membrane enters the superficial perineal pouch of Colles, and, after giving off the *transverse perineal a.* which runs along the base of the membrane to the central point of the perineum, continues as the *posterior scrotal a.* with the nerves of the same name to anastomose with the external pudendal branches of the femoral artery (3) *The artery to the bulb,* which, is a large vessel, runs in the deep pouch—a third of an inch from the base of the membrane to the bulb. (4) *The artery to the crus* (deep artery of the penis) which arises deep to the crus and at once enters it

At first the nerve lies above the artery, but on the dorsum of the penis, it lies lateral to the artery; and the veins of the two sides fuse to form a single, median, *deep dorsal vein,* which passes deep to the inferior pubic ligament to join the prostatic plexus of veins.

AXIOM Vessels that are paired and medianly placed in the embryo commonly fuse to form a single median vessel, e.g., the descending aorta, median sacral a., basilar a., sagittal venous sinuses, and the deep dorsal vein of the penis.

THE VASO-MOTOR NERVES to the cavernous tissue are derived from the pelvic splanchnic nerves (nervi erigentes) and the hypogastric plexus. They pass through the prostatic plexus and below the pubic arch to reach the erectile tissue

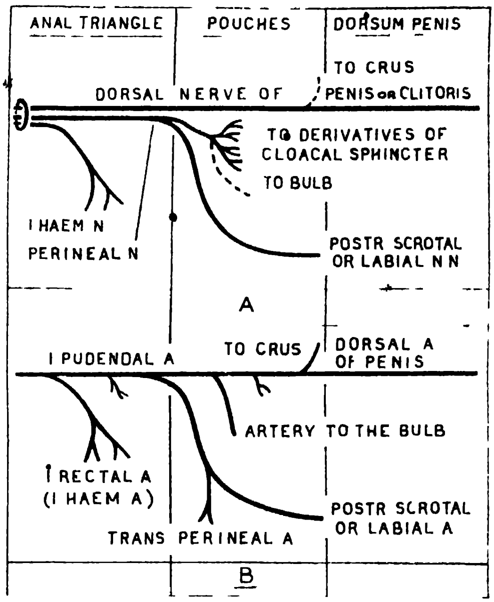


FIG 315. (A) The three *divisions* of the pudendal nerve. each for a region (B) The three *branches* of the pudendal artery. A necessary difference in terminology: an essential similarity in anatomy. N.B., The derivatives of the cloacal sphincter are: Bulbospongiosus, Ischio-cavernosus, Supf. Trans. Perinei, Deep Trans. Perinei, Sphincter Urethrae Externus, and the Sph. Ani Externus

of the corpora cavernosa and corpus spongiosum.

Exposure of Prostate Gland. Do not fail to get a glimpse of the prostate (*figs. 324, 313*). To do so: (1) First, make the separation of the anal and u. g. triangles complete by detaching the Sphincter Ani Externus from the perineal body. (2) Next, pull the anal canal and rectum backwards and define the anterior, free borders of the Levatores Ani. In doing

so, work with the point of the knife very strictly in the median plane because the free borders are but a third of an inch apart. (3) Then, keeping in mind the direction of the anal canal, insert the handle of the knife between the borders of the Levatores Ani, and ease the canal backwards. Areolar tissue and involuntary muscle (Recto-urethralis), joining the rectum to the base of the perineal membrane, require to be snipped through. (4) Lastly, proceed with the knife-

The Female Perineum

If you have familiarized yourself with the details of the male perineum, you will not have difficulty in appreciating the structure of the female perineum. The anal triangles are the same in the two sexes; the urogenital triangles differ. Perhaps the simplest way to begin is to plunge a knife into the male urethra, entering it on the under surface just behind the glans penis, and carrying an

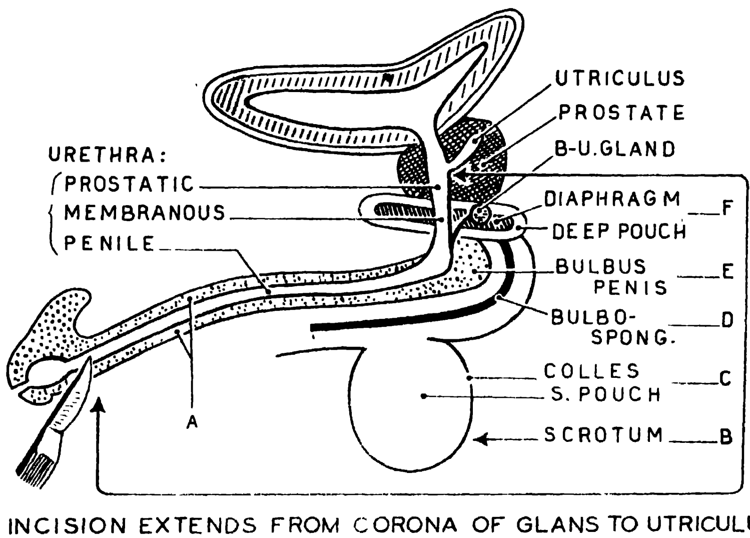


FIG. 316. Incision converting male perineum into female.

handle to push the structures developed from (and associated with) the anterior or urogenital part of the cloaca from the posterior or rectal part, and so expose the tough fascia covering the posterior surface of the prostate.

That you are able thus to expose the posterior surface of the prostate and the anterior surface of the rectum, from the skin surface, bloodlessly and without cutting a nerve, is due to the fact that the anal and urogenital triangles are supplied by separate branches of the internal pudendal vessels and nerves.

incision right back to the prostatic utricle and, in so doing, dividing everything encountered including the urethra, scrotum, Bulbo-spongiosus, bulb of the penis (urethra), and u. g. diaphragm. This you may do actually or in imagination (*fig. 316*). By this procedure you convert the male perineum into a female one or you restore it to the female condition, for in fetal life the male passed through the simpler female state. The different structures are common to both sexes, but their proportions, of course, differ. Thus: The female penis, called

the *clitoris*, is diminutive and is not traversed by the urethra. It comprises two *corpora cavernosa clitoridis* and a *glans clitoridis* which caps the conjoint corpora (*fig. 317*).

joining to form a band, the *frenulum of the clitoris*, which is attached to the under surface of the glans.

b. The scrotum is split into—right and left *labia majora.*

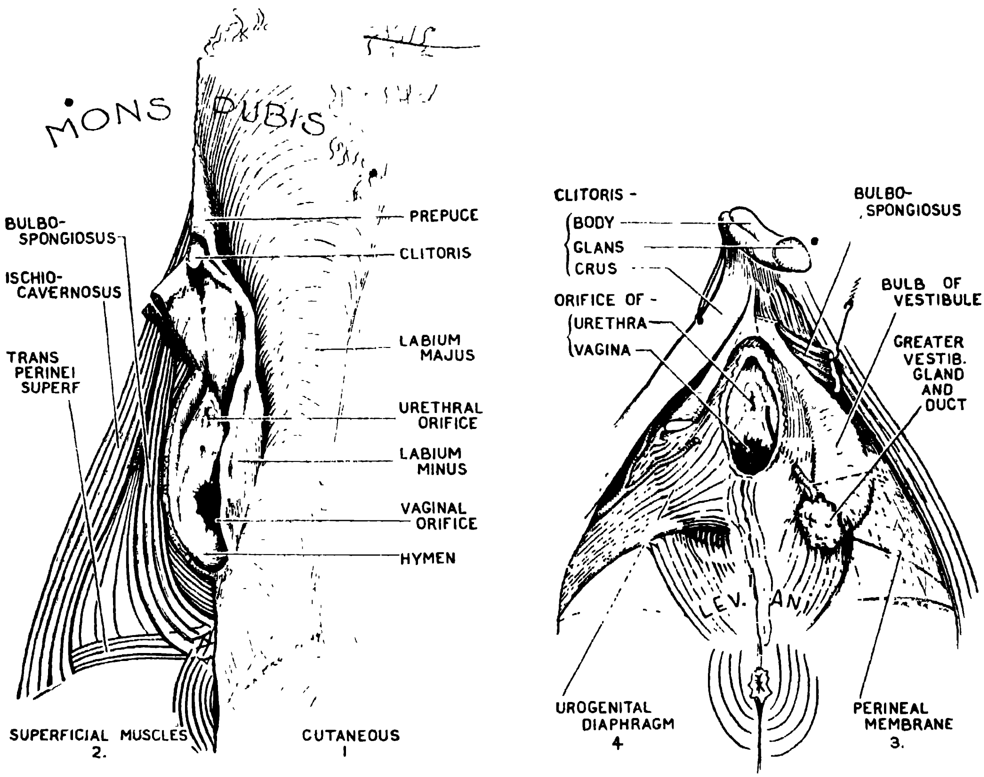


FIG. 317. Successive dissections (1, 2, 3 and 4) of the female urogenital triangle.

The incision suggested above would bring about the following changes and produce homologous female parts:

a. The edges of the incised urethra become—r. and l. labia minora.

Each *labium minus* is a thin cutaneous fold, devoid of fat and lying along side the orifice of the vagina. The posterior end is free. The anterior end divides into two lesser folds which unite with their fellows across the median plane, the upper folds forming a hood, the *prepuce of the clitoris*, over the glans, the lower

Each *labium majus* is a broad, rounded, cutaneous ridge lying lateral to the labium minus and covering a long finger-like process of fat. This extends backwards from a median skin-covered mound of fat, the *mons pubis* (mons Veneris) situated in front of the pubis and continuous with the fascia of Camper. Entering the fat of the labium from behind and running forwards are: the medial and lateral labial (cf. scrotal) nerves, arteries, and veins, and also the perineal branch of the posterior cutaneous nerve of the

thigh. Entering it from the front are: branches of the ilio-inguinal nerve and external pudendal artery and vein, and a fibrous cord, called the *round ligament of the uterus* (i.e., gubernaculum ovarii, (*fig. 358*).

Sebaceous glands open on to both surfaces of the labia minus and majus; hair covers the mons and the lateral surface of the labium majus.

c. The superficial perineal fascia and pouch into—r. and l. parts.

d. The Bulbo-spongiosus into—r. and l. parts (Sphincter Vaginae).

e. The bulb of the penis into—the r. and l. *bulbs of the vestibule.*

Each *bulb* is a loosely encapsuled mass of erectile tissue, shaped like a half-pear. The convex surface is lateral and is covered by the Bulbo-spongiosus; the flat or concave surface is medial and is applied to the perineal membrane which intervenes between it and the wall of the vagina; the enlarged end of the pear is posterior; the narrow stalk is anterior and, after joining its fellow, ends as the *glans clitoridis.*

f. The urogenital diaphragm, its inferior fascia (perineal membrane), and its superior fascia into—right and left parts.

g. The prostatic utricle comes to open on to the skin surface——the *vagina* (? uterus).

The *vestibule* of the vagina is the cleft between the labia minora. The *hymen* is a thin membranous fold of irregular outline that surrounds the vaginal orifice like the ruptured membrane of a drum.

h. The bulbo-urethral glands come to open on to the skin surface—the *greater vestibular glands* (Bartholin's glands).

Each *gland* is larger than a pea (it is smaller in the aged) and is covered by the hinder end of the bulb. Its duct, 2 cm. long, opens into the hinder part of the vestibule.

i. The remaining part of the urethra (i.e.. the part above the utricle) is homologous with the entire female urethra. In the male this part is $\frac{3}{4}''$ long; in the female it is $1\frac{1}{4}$ inches. The female urethra lies immediately in front of the anterior wall of the vagina and is intimately adherent to it. The *urethral orifice* opens just in front of the vaginal orifice and is one inch behind the glans.

j. The muscle fibers of the prostate are derived from the muscle fibers of the urethra, and the glands of the prostate are specialized urethral glands. Though a prostate is not found in the female, the *para-urethral glands* of Skene, whose ducts open one on each side of the female urethra, are probably homologous with prostatic glands.

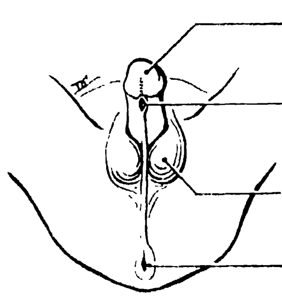


FIG. 318. Showing (a) the paired, right and left, labio-scrotal (genital) folds about to unite below the penis to form the scrotum, and (b) the urethral orifice moved forwards.

k. The ejaculatory ducts, which in the male open on to the lips of the prostatic utricle, (*fig. 341*) generally disappear in the female, but, as the ducts of Gartner (*fig. 49, p. 64*), they may persist as blind tubes on the anterior wall of the vagina, and become cystic; rarely they open on to the skin surface, as in the sow.

l. In the male, the primitive urethral orifice opened in the perineum, then when the lips of the genital folds met and fused, a secondary orifice was formed behind the glans penis (*fig. 318*); subsequently

the urethra traversed the glans; so, a third and permanent orifice opens at the end of the glans. In the female, the primary perineal orifice is the permanent one. The glans clitoridis is not canalized.

m. In the male, the gubernaculum testis passed to the scrotum, and the processus vaginalis peritonei and the testis followed it. In the female, the gubernaculum ovarii and the processus vaginalis (of Nuck) entered the labium majus but, owing to a side attachment which the gubernaculum makes with the uterus, the *ovary* enters the pelvis; only rarely does it descend into the labium (*fig. 358*).

CHAPTER 12

THE MALE PELVIS

Fundamental Embryological Considerations. The viscera contained in the true pelvis are either derived from the cloaca or are connected with it developmentally. The cloaca is an endodermal lined receptacle into which the gut opens posteriorly, and the allantoic duct (the urachus of postnatal life) anteriorly. A partition of mesoderm, called the *cloacal* or *urorectal septum* (*fig. 307*) growing down from above, divides the cloaca into: (a) an anterior portion the future bladder and part of the urethra, and (b) a posterior portion the future intestinum rectum and upper part of the anal canal. In this intermediate mesodermal septum the ureter and certain reproductive organs develop, namely

In the Male: the vasa deferentia, the seminal vesicles, and the prostate.

In the Female: the uterine tubes, the uterus, and the vagina.

The Pelvis Viewed from Above. From the preceding remarks it will be gathered that, on viewing a pelvis from above, one seeks the pelvic colon and rectum dorsally, the urachus and bladder ventrally, and the genital organs in the plane between the two.

The following *peritoneal fossae* are seen: on each side of the partly filled rectum, the *pararectal fossae*; on each side of the partly filled bladder, the *paravesical fossae*; and, between the rectum and the bladder, the *recto-vesical fossa*.

Follow the Peritoneum in the Median Plane (*fig. 319*) down the (1) anterior abdominal wall, (2) on to the back of the pubis, (3) across the superior surface of the empty bladder, (4) down its posterior surface for half-an-inch, (5) over the upper ends of the seminal vesicles which are capped with peritoneum on each side of the median plane, (6) across the bottom of the recto-vesical fossa, and on to the rectum. Where the rectum bounds the recto-vesical fossa it is covered with peritoneum in front only; a little higher where it bounds (7) the pararectal fossa it is clothed with peritoneum in front and on the sides; above

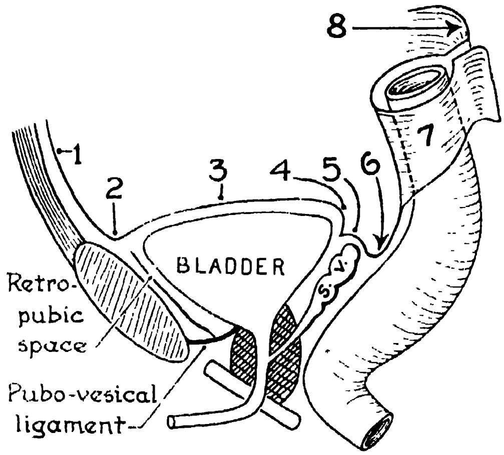


Fig. 319. The peritoneum of the male pelvis in paramedian section (see text and fig. 356).

the level of the 3rd piece of the sacrum (8) the gut acquires a mesentery and the name rectum gives place to pelvic colon.

Detach the Peritoneum from the right half of the pelvic brim and note that 4 "visceral tubes" adhere to it even when detached (*fig. 320*). They are (a) the pelvic colon and rectum dorsally; (b) the urachus and bladder ventrally; and (c) the ureter, and (d) vas deferens laterally.

Before cutting peritoneum, even though mobilized and detached, the sur-

geon makes sure that the ureter in particular is safe.

RAISE THE BLADDER and pull it back from the symphysis and thereby open up **the Retro-pubic Space of Retzius.** This extensive bursa-like cleft in the areolar tissue at the sides and front of the bladder allows the bladder to fill and empty without hindrance. The space is bounded *medially* by the infero-lateral surface of the bladder; *laterally* from above downwards by pubic bone, fascia clothing the Obturator Internus, and fascia covering the Levator Ani; *below*

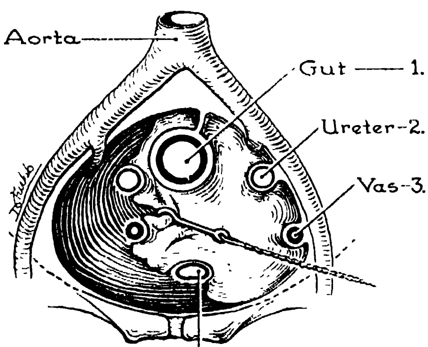


FIG. 320. Four visceral tubes adhere to the peritoneum. (The peritoneum has been detached from the side wall of the pelvis.) In the female substitute ovarian vessels for vas deferens.

by the reflexion of this fascia on to the bladder (*fig. 321*); *above* by the peritoneum passing from the upper surface of the bladder to the side wall of the pelvis. The two sides of the space are continuous *in front*, between the symphysis pubis and the anterior border of the bladder. With the exploring finger observe that the space is limited *posteriorly* by a broad areolar fold enclosing a leash of vessels that pass from the internal iliac artery and vein to the posterior-lateral border of the bladder (*fig. 350*). With the finger-tip placed on the fascial floor of the space, feel two taut cord-like thickenings, one on each side of the median plane, that attach the neck of the bladder to the lower end of the symphysis; these are the *pubo-vesical* or *pubo-prostatic ligaments* (*fig. 325*).

THE SUBPERITONEAL URETER AND THE SUBPERITONEAL VAS DEFERENS. Before following these, glance again at figure 283 and recall that during the migration of the kidney upwards, and of the testis downwards, the testis crossed in front of the ureter and drew the testicu-

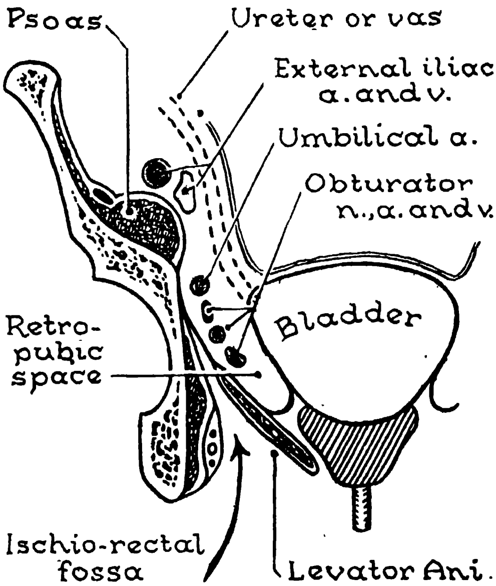


FIG. 321. The side wall of the male pelvis on coronal section (diagrammatic).

lar vessels and the vas deferens after it. The testicular vessels cross in front of the ureter in the abdomen; the vas deferens crosses in front of the ureter in the pelvis—close to where it enters the bladder.

Follow the *right ureter* from the point at which it crosses the external iliac artery, just in front of the bifurcation of the common iliac artery, to the lateral angle of the bladder where its last inch is enveloped in the leash of vessels just mentioned, and is crossed by the vas

deferens. Trace the *right vas deferens* from the deep inguinal ring, where it turns round the inferior epigastric vessels, to the lateral angle of the bladder where it crosses anterior to the ureter.

THE ORGANS THAT DEVELOPED IN THE PRIMITIVE URORECTAL SEPTUM may now be exposed, provided the bladder is contracted and firm. These are the seminal vesicles which are situated laterally and the vasa deferentia which lie between the vesicles and project upwards from the prostate within a fascial fold, the *recto-vesical fascia* (*fig. 325*). Thus, pull the bladder forwards and thereby obtain

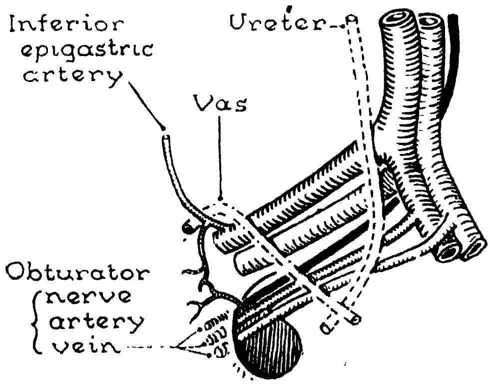


FIG. 322. The structures on the side wall of the male pelvis. Note the medial positions of the ureter and vas.

room to incise the peritoneum transversely at the base of the bladder; then with the rounded handle of the knife, ease the enveloping fold backwards off the bladder, and then forwards off the rectum. This is easily done by blunt dissection without damaging the investing fascia.

The Side Wall of the Pelvis. *The false or greater pelvis* comprises the iliac fossae and the alae of the sacrum (*fig. 328*) clothed with Iliacus and Psoas which in turn are covered with fascia iliaca (*fig. 321*). No muscle crosses the pelvic brim—this is fortunate, for so placed it would offer obstruction to childbirth—hence, the fascia iliaca is free to gain attachment to the brim. The common and external iliac arteries and veins lie in the extraperitoneal tissue first medial to the Psoas, and then in front of it, its fascia intervening. The internal iliac artery (hypogastric a.) crosses the pelvic brim. As it does so, it crosses medial to the external iliac vein and is accompanied by its own vein behind, and by the ureter in front (*fig. 322*).

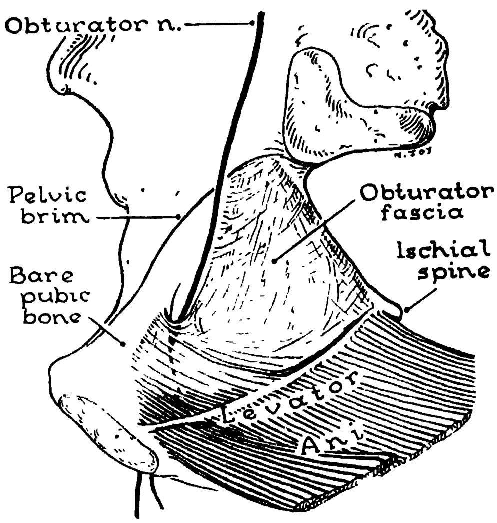


FIG. 323. The side wall of the lesser pelvis divided into upper and lower (anterior and posterior) parts by the obturator nerve.

The side wall of the true or lesser pelvis is now to be examined on the right. For this, forceps may be required, but no dissection is necessary.

The peritoneum with the adhering ureter and vas deferens has already been detached from the brim and drawn medially, and the retropubic space of Retzius has been explored.

The side wall may be divided into two parts: the part above the obturator nerve and the part below it (*fig. 330*). *Above the nerve*, the wall is formed by

bare pubic bone; *below* it, by the obturator Internus and its fascia.

What is the line of the nerve? The obturator nerve arises from the anterior rami of L. 2, 3 and 4, and takes a straight course to the obturator foramen through which it passes into the thigh. In its course it crosses, but does not touch, the ala of the sacrum, pierces the psoas fascia at the medial border of the Psoas, crosses the pelvic brim lateral to the bifurcation of the common iliac vessels, and runs on the pubic bone to the upper end of the obturator foramen. The Obturator Internus, covered with its fascia, rises posteriorly to the pelvic brim, but falls anteriorly below the upper part of the obturator foramen leaving the pubic bone exposed and allowing the obturator nerve, artery, and vein to escape from the pelvis via the foramen without piercing muscle or fascia. The obturator nerve springs from the lumbar plexus and, so, is above the obturator artery and vein which springs from the internal iliac vessels; and, according to RULE, the artery occupies the intermediate position; i.e., from above downwards the order is: nerve—artery—vein.

The Levator Ani, which forms part of the pelvic floor or diaphragm, is seen arising from the inner surface of the body of the pubis, from the inner surface of the ischial spine, and, between these two points, from the obturator fascia, which is commonly thickened to form a *tendinous arch* of origin.

From above downwards, then, the side wall is formed by the Psoas and its fascia, the pelvic brim, bare pubic bone (anteriorly), Obturator Internus and its fascia.

As your finger is passed downwards into the true pelvis, the structures encountered on the side wall are successively: the external iliac artery, the external iliac vein, the obturator nerve, artery, and vein, all of which are somatic structures going to the lower limb. These are succeeded by the Levator Ani which forms part of the floor (*fig. 350*). [Being above the pelvic brim, the Psoas, its fascia, and the external iliac vessels, in a strict sense, belong to the false pelvis.] The ureter and the vas deferens, being extraperitoneal viscera, descend on the medial side of the structures enumerated.

Running forwards from the internal iliac artery to the umbilicus is the allantoic—placental—umbilical—or obliterated hypogastric artery, whichever you prefer to call it. It is a visceral vessel which primitively supplied the allantoic end of the cloaca and the allantois; so, you will appreciate why it tends to adhere to the side of the bladder and to supply it with superior vesical branches. Beyond these branches it is obliterated.

The Pelvic Fascia (*fig. 325*). Just as all articles thrown into a basin of water become wet all over, so all the contents of the pelvis, whether they be muscles, viscera, or vessels, are covered all over with areolar tissue—in fact, with the areolar mesodermal tissue that in embryonic life filled the pelvic basin. This is perhaps not more true of the fascia of the pelvis than of the fascia of the abdomen or thorax; but the pelvic fascia attracts more attention. The covering given by this areolar tissue to organs that expand and contract, notably the rectum and bladder, is necessarily loose: that given to organs that do not expand may be dense, as in the case of the prostatic fascia, or loose as in the case of the fascia covering the seminal vesicles and vasa deferentia. Its texture depends upon the strains put upon it. Naturally, the fascia takes the shape of the surface it covers, forming a sheet where it covers a flat muscle or organ,

forming a tube where it envelops a tubular structure, and blending with the periosteum where it covers exposed bone.

From the nature of its origin you will readily understand that though the different parts of the fascia are referred to as layers, they are not independent like sheets of paper, but are parts of a single whole, like the septa of a sponge.

ticular coverings these viscera receive are called the *vesical*, *rectal*, and *recto-vesical layers* respectively of the pelvic fascia.

You should certainly establish the following points:

1. Just as the iliac bone together with the fascia iliaca forms a strong osseo-fascial pocket for the Ilio-psoas, so do the ischial and pubic bones together with

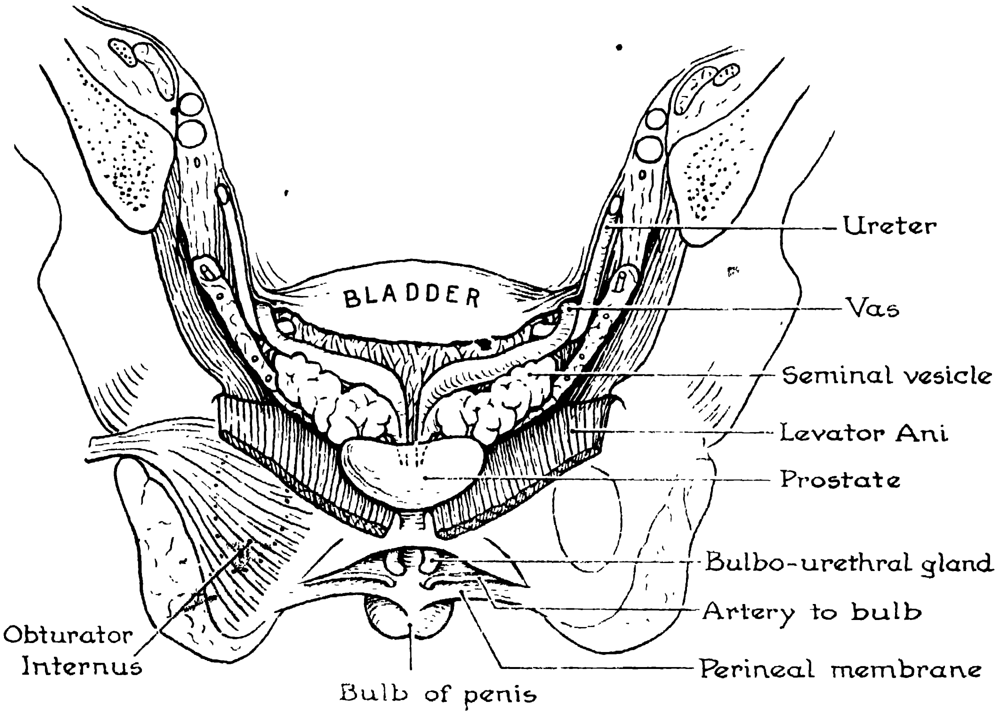


FIG. 321. A coronal section of the pelvis to show the genito-urinary organs from behind.

SUBDIVISIONS OF THE PELVIC FASCIA. This fascia may be divided into *parietal*, *diaphragmatic*, and *visceral* layers: (a) The parietal layer covers the Obturator Internus at the side and the Piriformis at the back; (b) the diaphragmatic layer covers the upper surface of the pelvic diaphragm (or floor) formed by the Levator Ani and Coccygeus; and (c) the visceral layer covers the bladder, the rectum, and the genital organs in between the bladder and the rectum; and the par-

the obturator fascia form an osseo-fascial pocket for the Obturator Internus. (*fig.* 323, 330).

2. In the perineum the pelvic fascia has already been observed to give a complete lining to the ischio-rectal fossa; the lining being stronger laterally over the Obturator Internus than medially over the Levator Ani and Sphincter Ani Externus. It has also been seen to form "the superior and inferior fasciae of the urogenital diaphragm", which are

continuous with each other at the apex and base of the diaphragm.

3. The floor of the retro-pubic space of Retzius is lined with a broad sheet of fascia which is continuous at the neck

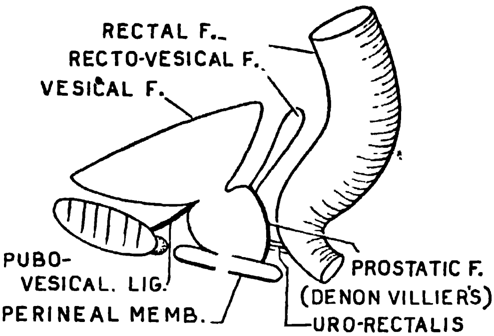


FIG 325. The pelvic fascia of the male in median sagittal section.

Pelvic Girdle				*Pectoral Girdle*
	Os Ilium	homologue	Scapula	Fuse at 15th year in glenoid cavity
Fuse at 16th year in acetabulum	Os Ischii		Coracoid	
	Os Pubis		Clavicle	

of the bladder with the vesical fascia. The portion of this sheet that passes forwards to the pubis has developed in it two bands, the *pubo-vesical* or *pubo-prostatic ligaments*, which help to anchor the bladder and prostate and can easily be felt. The portion that spreads laterally covers the Levator Ani and blends with the obturator fascia and with the periosteum of the pubis.

4. Pass the handle of the knife through the roof of the ischio-rectal fossa into the retro-pubic space of Retzius and note how thin the partition is (*figs. 309, 321*).

5. Pull the bladder to the left and note that, at the posterior limit of the retro-pubic space, the fascia invests the numerous veins and few arteries that are passing from the base of the bladder and internal genital organs (within the recto-vesical fascia) to the internal iliac vessels.

6. Be satisfied that four layers of fascia separate the bladder from the rectum. They are the layer clothing the base of the bladder; the layer clothing the front of the rectum; and two other layers of which one clothes the vasa deferentia and seminal vesicles in front, the other clothes them behind (*fig. 325*).

7. The dense fascia clothing the back of the prostate was partially investigated from the perineum. Note now that a finger, or the handle of a knife, passed downwards between the rectum and the genital organs enters the perineum. That it should be possible for it to do so will be appreciated when it is understood that in foetal life the recto-vesical pouch of peritoneum extended downwards between the rectum and the prostate. It became obliterated, but it can be opened up again (*fig. 253*).

8. Pass two fingers downwards behind the rectum and ease it forwards off the front of the sacrum and coccyx. The fingers occupy a little pouch bounded on each side by an areolar fold that contains the pelvic splanchnic nerve (nervus erigens, S. 2, 3, 4) and conducts them from the 2nd, 3rd, and 4th anterior sacral foramina to the side of the rectum.

9. The blood vessels of the pelvis are branches of the internal iliac vessels, so, they lie inside (on the peritoneal aspect of) the pelvic fascia and require to pierce the fascia in order to escape from the pelvis. The nerves, on the other hand,

emerge from the anterior sacral foramina and, so, are outside the fascia. The obturator nerve and the lumbo-sacral trunk, however, pierce the psoas fascia above the pelvic brim, cross the brim, and come to lie inside the fascial lining of the pelvis.

The Interior of the Bony Pelvis. Pelvis is Latin for a basin. The pelvis is formed by—the right and left hip bones, the sacrum, and the coccyx. The two hip bones articulate with each other in front at the symphysis pubis; behind they articulate with the first three sacral vertebrae at the sacro-iliac joints. The right and left hip bones constitute the pelvic girdle.

Each hip bone has three fundamental parts *ilium*, *ischium*, and *pubis*. Of these, the ilium and ischium have homologous parts in the pectoral girdle. The pubis, however, is not represented in the pectoral girdle, neither is the clavicle represented in the pelvic girdle, but they have analagous functions to perform (*fig. 333*). The pectoral girdle is free and mobile, whereas the pelvic girdle is built for stability and is united to the vertebral column.

The Os Sacrum is composed of 5 fused vertebrae, and **the os coccygis** of 3–5, though before birth it has 7–11 cartilaginous caudal rudiments. Both sacrum and coccyx are triangular with base above and apex below (*fig. 326*).

THE BASE OF THE SACRUM, in reality the upper surface of the first sacral vertebra, is divided into three parts—a median and two lateral. The median part is the oval upper surface of the body of the first sacral vertebra. Its anterior border is an important landmark named the *promontory* of the sacrum. Behind its posterior border is situated the somewhat compressed triangular entrance to the *sacral canal*. This is guarded by prominent superior articular processes, extremely short pedicles, well developed laminae, and a much reduced spinous process. The right and left lateral parts, called the *alae*, are fan-shaped and represent fused costal and transverse elements (*fig. 28*).

Each ala is crossed by the constituents of the lumbo-sacral trunk, the ilio-lumbar artery, the obturator nerve, and the Psoas. Of these nerves, the fifth lumbar anterior ramus is so taut that it grooves

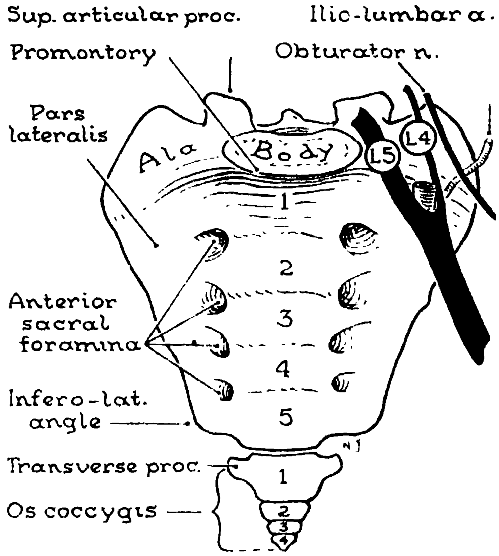


FIG. 326. The anterior aspect of sacrum and coccyx (with sacral plexus).

the surface and anterior border of the ala; the branch of the fourth lumbar nerve is closely applied to the anterior border; whereas the obturator nerve is above, but not in contact with, the ala.

THE CONCAVE ANTERIOR SURFACE of the sacrum is crossed by four rough ridges at the sites where fusion took place between the bodies of the five sacral vertebrae before the 21st year. Lateral to the four ridges, on each side, are the four *anterior sacral foramina*. Their margins are smooth and rounded laterally, because

the emerging anterior rami of the upper four sacral nerves pass laterally; but medially they are well defined and sharp. Though the sacrum as a whole tapers from above downwards, the width of the bodies does not diminish appreciably, so the foramina of the two sides do not become appreciably closer to each other. The mass of bone lateral to the foramina is called the *lateral mass* (pars lateralis). It is deeply grooved by the upper four anterior nerve rami.

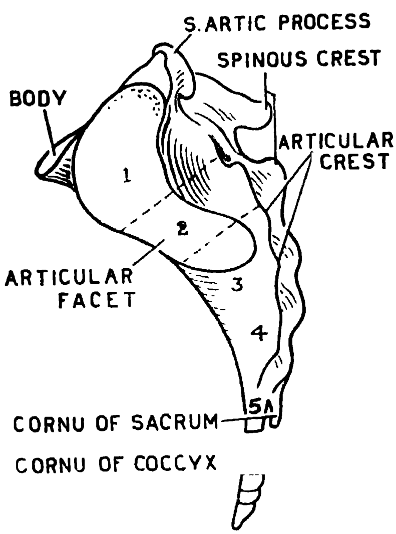


FIG. 327. The lateral aspect of sacrum and coccyx.

THE SIDES of the upper three pieces of the sacrum form a large *auricular* or *ear-shaped facet* which articulates with a corresponding auricular facet on the ilium (*fig. 327*); the sides of the lower two pieces, as well as the sides of the coccyx, are thin for the sacro-tuberous and sacro-spinous ligaments (*fig. 335*).

THE APEX of the sacrum is the lower articular surface of the fifth body, compressed antero-posteriorly to articulate with the body of the first piece of the coccyx.

THE FIRST PIECE OF THE COCCYX possesses a pair of *transverse processes* each of which is joined by a ligament to the lowest "transverse process" of the sacrum (infero-lateral angle) thereby making a foramen through which the anterior ramus of the fifth sacral nerve enters the pelvis. The remaining pieces of the coccyx are nodular. The 1st piece commonly fuses with the sacrum, which then has six pieces; the joint between the 1st and 2nd pieces of the coccyx then commonly persists.

The Pelvic Brim is the boundary line between the greater or *false pelvis* above

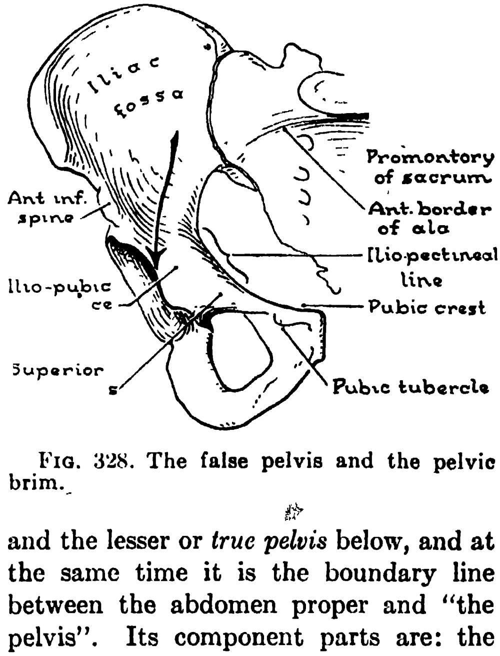


FIG. 328. The false pelvis and the pelvic brim.

and the lesser or *true pelvis* below, and at the same time it is the boundary line between the abdomen proper and "the pelvis". Its component parts are: the promontory of the sacrum, the anterior border of the ala of the sacrum, the ilio-pectineal line [which extends from the ala to the pubic tubercle], the pubic crest, and the upper end of the symphysis pubis (*fig. 328*). The alar portion of the brim is weight-transmitting and therefore thick; the lumbo-sacral trunk and the ilio-lumbar artery curve over it, but no fascia is attached to it; so, it is rounded. The posterior half of the ilio-pectineal

line is formed by the ilium; the anterior half by the pubis; and a rough elevation, the *ilio-pubic eminence* (ilio-pectineal eminence), marks the site of their union. The iliac portion of the ilio-pectineal line has attached to it the fascia iliaca and the obturator fascia; so, it is sharp, and when a Psoas Minor is present a crest generally rises from this portion of the brim.

The pubic part of the ilio-pectineal line, called the *pectineal line* (pecten pubis), is sharp because it gives attachment in its whole length to the fascia covering the Pectineus, and in its medial three-quarters of an inch to the pectineal part of the inguinal (lacunar) ligament and to the conjoint tendon. A strong fibro-cartilaginous band, ***pectineal*** (Cooper's) ***ligament***, through which a needle and thread can get a good grip, follows the line.

The triangular portion of the os pubis lying in front of the pectineal line, and extending from the ilio-pubic eminence to the pubic tubercle, is the pectineal surface of the superior ramus of the pubis. It belongs to the lower limb—not to the false pelvis.

The False or Greater Pelvis (Pelvis Major (*fig. 328*) is formed on each side by the ala of the sacrum, just described, and the iliac fossa. *The iliac fossa* is fan-shaped, concave, and, because the Iliacus which covers its entire surface is fleshy, it is smooth. The anterior two-thirds of the iliac crest forms the base of the fan and bounds the fossa above. The iliac tuberosity, the auricular surface, and the iliac part of the ilio-pectineal line bound it medially (*fig. 335*). The handle of the fan lies immediately above the acetabulum and is represented by a broad groove situated between the ilio-pubic eminence and the anterior inferior iliac spine. In this groove the Psoas tendon plays, but is separated from the bone and the capsule of the hip joint by the intervening Psoas (pectineal) bursa.

The True or Lesser Pelvis (Pelvis Minor) is formed behind by the anterior surfaces of the sacrum and coccyx, just described. In front and at the sides it is formed by the inner surface of the ischium and pubis, and by a small triangular part of the ilium that descends below the brim as far as a line joining the ilio-pubic eminence to the greater sciatic notch (*fig. 329*). Though small, this part of the ilium is an essential part of the pelvis, for it is weight-transmitting

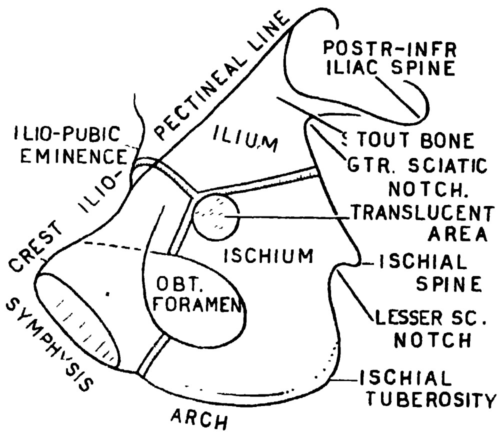


FIG. 329. The lateral wall of the lesser pelvis.

and therefore very thick; it extends backwards below the auricular surface.

These parts of the pubis, ischium, and ilium together form a triangular, concave, smooth area. The base of this triangle is formed by the pubic crest and the ilio-pectineal line; the apex is the ischial tuberosity; one side is formed by the symphysis pubis, the inferior ramus of the pubis, and the ramus of the ischium, the rami being conjoint to form one side of the pubic arch; and the other side is formed by the greater and lesser sciatic notches and the ischial spine which separates them.

The oval *obturator foramen* separates the pubis in front and above from the ischium behind and below. The margin of the foramen forms a spiral which extends from the ilio-pubic eminence inside the pelvis to the pubic tubercle outside. The ends, then, do not meet, but bound the *obturator groove* on the under surface of the superior ramus of the pubis. Through this groove the obturator vessels and nerve escape from the pelvis. The ischium is thin and translucent immediately above the obturator foramen because here it forms the bottom of the non-articular part of the acetabulum.

Observation. A multiplicity of triangular or fan-shaped areas enter into the composition of the false and true pelves: the sacrum, the entrance to the sacral canal, the alae of the sacrum, the coccyx; the iliac fossae; the side wall of the true pelvis, the part of the ilium that crosses the pelvic brim, the bare part of the pubis above the line of the obturator nerve, the pubic arch, and the ischial spine.

THE FORAMINA IN THE WALLS OF THE TRUE PELVIS. The posterior wall of the true pelvis is perforated by the 4 *anterior sacral foramina.* A probe entering one of these will emerge through the corresponding, much smaller posterior sacral foramen on to the dorsum of the sacrum. Two ligaments, namely, the *sacro-tuberous* and *sacro-spinous*, so unite the posterior wall to the side wall as to leave two gaps, the *greater* and *lesser sciatic foramina figs. 335, 338*). The large, oval *obturator foramen* lies near the front of the side wall between the pubis and the ischium. It is closed by the obturator membrane except above where a gap, through which the little finger can be passed, transmits the obturator nerve and vessels, and may be the site of a hernia.

THE MUSCLES AND FASCIA LINING THE WALLS OF THE TRUE PELVIS. *The Obturator Internus* arises by fleshy fibers from almost the entire inner surface of the side wall of the true pelvis below the line of the obturator nerve (*fig. 330*); that is to say, it does not encroach upon the body and superior ramus of the pubis, but leaves them bare and free to afford part origin to the Levator Ani. The Obturator Internus leaves the pelvis through the lesser sciatic foramen.

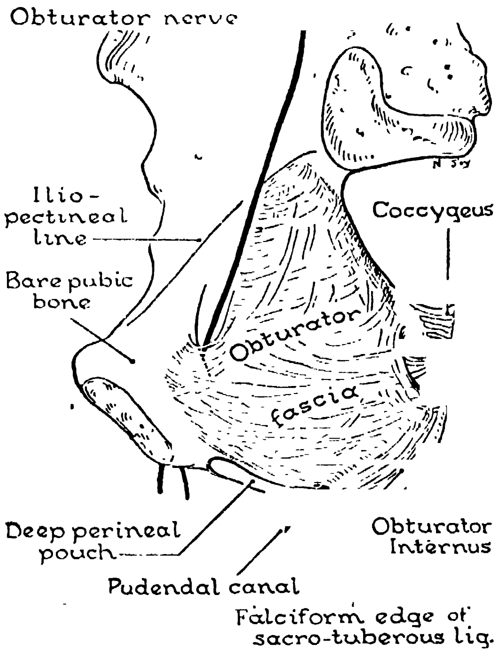


FIG. 330. The Obturator Internus Fascia

The Piriformis arises by fleshy fibers from the 3 bars of bone that separate the 4 anterior sacral foramina and from the lateral mass. It leaves the pelvis through the greater sciatic foramen.

The obturator fascia is thin above and thicker below; and with the side wall of the pelvis it forms an osseo-fibrous pocket for the Obturator Internus, comparable with the osseo-fibrous pocket for the Ilio-psoas. It is attached to the hip bone around the margin of its muscle; that is, to the border of the greater sciatic notch,

to the iliac part of the ilio-pectineal line, along the line of the obturator nerve, to the pubic arch, and to the ischial tuberosity through the medium of the falciform edge of the sacro-tuberous ligament; but of course it is not attached to the border of the lesser sciatic notch, this being the site of the *mouth of the pocket* through which the muscle escapes from the pelvis. Its lower part is tunnelled by the pudendal canal.

The fascia covering the Piriformis is areolar and weak.

The Pelvic Diaphragm. The Levator Ani and Coccygeus of opposite sides

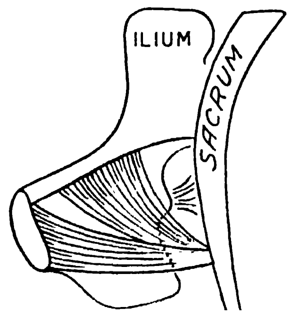


FIG. 331. The pelvic diaphragm of the monkey (After Keith.)

stretch across the pelvis and form for it a concave floor that separates it from the perineum. This diaphragm, like the abdomino-thoracic diaphragm, is composed of voluntary muscle and is perforated by several canals—the urethra and the rectum and, in the female, by the vagina also.

The pelvic diaphragm arises in front from the body of the pubis, behind from the spine of the ischium, and between these two points from an arched thickening of the obturator fascia, called the *tendinous arch* (arcuate line).

Phylogenetically, the diaphragm consists of 3 separate caudal muscles—the Pubo-coccygeus, the Ilio-coccygeus, and the Ischio-coccygeus, which in tailed mammals act upon the tail (*fig. 331*). In man, whose carriage is erect and whose tail is reduced to a coccyx, the muscles are modified:

The Pelvic Diaphragm

1. Pubo-coccygeus }
2. Ilio-coccygeus } = Levator Ani
3. Ischio-coccygeus = Coccygeus

The Ischio-coccygeus or Coccygeus stretches like a fan from the ischial spine to the sides of the free segments of the sacrum (i.e., 4th and 5th) and to the coccyx. In the dog the Coccygeus wags the tail; in man it is largely transformed into the sacro-spinous ligament. Some

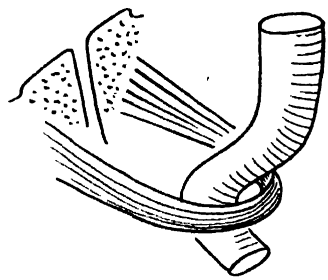


FIG. 332. "The pubo-rectal sling."

fleshy fibers, however, persist on the pelvic surface of the ligament, and they may form a complete fleshy sheet coextensive with the ligament.

The Ilio-coccygeus, formerly attached to the pelvic brim, has—as it were—atrophied above, become fibrous, and blended with the periosteum and with the obturator fascia above the level of the tendinous arch (*fig. 350*). It is inserted into the coccyx and into the ano-coccygeal raphe that stretches from anus to coccyx.

The Pubo-coccygeus, which is the thickest and most important part of the diaphragm, runs downwards and backwards from the pubis and meets its fellow (a) in the perineal body in front of the anus

and (b) in the ano-coccygeal raphe behind the anus; between the two (c) it is carried down by the rectum and anal canal, which perforate it and with which it blends. On the deep or pelvic surface of the muscle many fibers pass from pubis to coccyx; others meet those of the opposite side in the angle between the rectum and anal canal and so form a U-shaped sling that maintains this angle (*fig. 332*). The different parts of the diaphragm, though overlapping somewhat, blend to form a single sheet.

The Coccygeus and the sacro-spinous ligament have a free posterior border. The Levator Ani has a free anterior border which is separated from its fellow by a third of an inch. Between the anterior borders the prostate can be exposed from the perineum (p. 315). The urethra and, in the female, the vagina pass between the anterior borders.

Actions. The pelvic diaphragm supports the pelvic viscera. Figures 319, 324, and 355 demonstrate that the integrity of the pelvic floor depends especially on the Pubo-coccygeus, including the pubo-rectal sling, since these hold forwards the lower part of the rectum, which in turn helps to support the bladder and seminal vesicles in the male, and the bladder and vagina in the female. The pubo-rectal sling keeps the ano-rectal angle closed, but during defaecation it relaxes and allows the ano-rectal junction to straighten, while other fibers draw the anal canal over the faeces that are being expelled. The anterior fibers of the muscle support the prostate in the male and, which is more important, the vagina in the female.

Nerve Supply. Branches from S. (2), 3, and 4 supply the muscle on its pelvic surface; twigs of the inferior haemorrhoidal n. (S. 2, 3, and 4) supply it on its perineal surface.

Orientation of the Pelvis. In the "neutral" position of the pelvis the anterior superior iliac spines and the top of the symphysis are in a vertical plane. This is readily found by applying the pelvis to a wall or a window. The acetabular notch then looks downwards and very slightly forwards; the ischial spine is a little above the level of the top of the symphysis pubis, and the tip of the coccyx is a little below it. In the male the a. s. spines fail by about half-an-inch to reach the vertical; so, the coccyx is behind the upper half of the symphysis. In the female the a. s. spines overstep the vertical by about half-an-inch; so, the coccyx is on a level with the top of the symphysis. In compensation for the forward tilting of the pelvis in the female, the lumbar curvature of the spine is increased and the erect posture thereby maintained. Hence, the lower part of the back, which is nearly flat in the male, is markedly concave in the female; the buttocks are more prominent than in the male; so is the lower part of the abdomen; and the ilio-femoral ligaments are shorter.

The Lumbo-sacral Articulation. The joint between the 5th lumbar vertebra and the sacrum is an intervertebral joint possessing two peculiar ligaments on each side: (a) the ilio-lumbar ligament and (b) the lateral lumbo-sacral ligament.

The Ilio-lumbar Ligament is the greatly thickened lower part of the fascia covering the Quadratus Lumborum; the lateral arcuate ligament (lat. lumbo-costal arch, p. 301) being the slightly thickened upper part of this fascia. On each side, this strong ligament stretches from the tip of the 5th lumbar transverse process to the iliac crest in front of the attachment of the Quadratus. The ilio-lumbar ligaments limit rotation of the 5th vertebra on the sacrum and they assist the articu-

lar processes in preventing forward gliding of the 5th vertebra on the sacrum.

The 4th lumbar vertebra lies at the level of the highest parts of the iliac crests; the 5th vertebra lies below this level and, so, it alone is in a position to be suspended from the crests. The large size, the upward tilt, and the conical shape of the 5th lumbar transverse processes are dependent on this fact—note that the bases of the processes spread forwards from the pedicles (roots) of this vertebra on to the body.

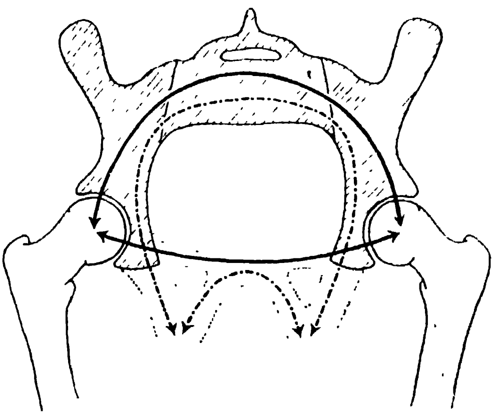


FIG. 333. The mechanism of the pelvis Solid lines = the standing arch and its tie beam or counter arch which, like the clavicle, resists compressive forces. Broken lines = the sitting arch and its tie beam or counter arch which resists spreading forces. (After Braus.)

The Lateral Lumbo-sacral Ligament is a modified inter-transverse ligament. It spreads, as a sheet, downwards and laterally from the 5th lumbar transverse process to the ala of the sacrum. It has a sharp medial edge which abuts against the anterior ramus of the 5th lumbar nerve.

The typical ligaments of this joint are as follows:

The intervertebral disc is much thicker than other intervertebral discs; so, more movement is permitted here than between other vertebral bodies. The bodies are narrower from front to back than from side to side; so, flexion and extension should be greater than side to side bending, provided the articular processes permit, and they do. The disc is so much deeper in front than behind that it contributes to the lumbar curve and, therefore, to the erect posture. The anterior and posterior longitudinal ligaments descend to the first piece of the sacrum. The laminae are united by ligamenta flava; the spinous processes by supra- and inter-spinous ligaments; the articular processes by loose capsules.

The Mechanism of the Pelvis (*fig. 333*). The weight of the body super-

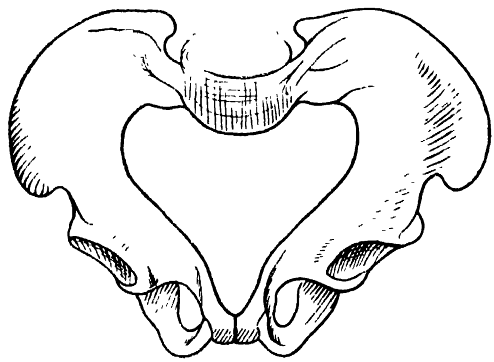


FIG. 334. Pelvis from case of osteomalacia, The femora have driven in the softened bones.

imposed on the 5th lumbar vertebra is transferred to the base of the sacrum, thence to the upper three pieces of the sacrum, across the sacro-iliac joints to the ilia, and thence (a) when standing up—to the acetabula and so to the femora, or (b) when sitting down—to the ischial tuberosities. Along these lines the bony parts are thickened. In the standing posture, the acetabula and the side walls of the pelvis tend to be forced together, but the pubic bones, acting as struts, prevent this from happening. In cases of softening of the bones (osteomalacia) the side walls are

actually driven in and the pelvis assumes a beak-shape (*fig. 334*). In the sitting posture the ischial tuberosities tend to be forced apart—in rickets they actually are.

Many mammals possess a symphysis ischii as well as a symphysis pubis and so have a powerful strut. In birds the pubic bodes are wide apart and, so, offer no obstruction to the laying of eggs.

The Joints of the Pelvis are (1) the sacro-coccygeal, (2) the symphysis pubis, and (3) the right and left sacro-iliac joints.

The Sacro-coccygeal Joint is an atypical intervertebral joint. The bodies, transverse processes, and cornua of the last sacral and 1st coccygeal vertebrae are united by an intervertebral disc and by ligamentous bands. And, a very tough membrane, which is a downward prolongation of the supraspinous and interspinous ligaments, closes the sacral canal posteriorly and extends to the posterior surface of the coccyx.

Attached to each side of the coccyx and to each side of the lower two pieces of the sacrum (i.e., below the auricular surface) are: the Coccygeus, sacrospinous and sacrotuberous ligaments, and Gluteus Maximus. Movement backwards of the coccyx takes place on defecation and on parturition.

The Symphysis Pubis. Here as between the bodies of two vertebrae, the opposed bony surfaces are coated with hyaline cartilage and are united by fibro-cartilage. In the fibro-cartilage a cleft generally appears. Dense anterior decussating fibers and a strong inferior pubic (arcuate) ligament unite the pubic bones.

Age changes. The surface and margins of the pubic symphysis undergo progressive metamorphoses, especially between the 20th and 40th years, which serve as a criterion of age. Todd has divided this into ten phases. Phase (1) horizontal ridges and furrows; margins not defined (ae 18–19). (2) Furrows filling up dorsally; dorsal margin defined (ae 20–21). (3) Bevelling or rarefaction of ventral strip (ae 22–24). (4) Increased ventral erosion; beginning formation of lower end (ae 25–26). (5) Upper end beginning to form (ae 27–30). (6) Increasing definition of ends and formation of ventral margin (ae 30–35). (7) Quiescent; granular texture becoming finely grained; lipping at attachment of sacro-tuberous ligament and gracilis aponeurosis (ae 35–39). (8) Smooth surface; complete oval outline (ae 39–44). (9) Uniform dorsal and irregular ventral lipping (ae 45–50). (10) Erosion of surface and breaking down of ventral margin (ae 50 and upwards)

The Sacro-iliac Joint. The bony surfaces concerned are: (A) The part of the *internal surface of the ilium* behind the iliac fossa. This part is bounded above by the iliac crest, below by the greater sciatic notch, and behind by the posterior superior and posterior inferior iliac spines and the slight notch between them (*fig. 335*). It is subdivided into 2 parts: a lower, the *auricular surface;* and, an upper, the *tuberosity.* The auricular or ear-shaped part articulates with the sacrum, is covered with cartilage, and is traversed by a longitudinal sinuous ridge. The ilio-pectineal line begins at its most anterior part. The tuberosity is rough and tubercular for the numerous short fibers of the strong interosseous sacro-iliac ligament. (B) *The sacrum* possesses the counterpart: thus, on the side of the lateral mass there is an *auricular surface* with a sinuous furrow. This auricular surface extends on to the 3rd sacral segment but leaves the lower two segments free and attenuated for the sacro-spinous and sacro-tuberous ligaments. Behind the auricular surface is the *sacral tuberosity* (*fig. 327*).

Structural Requirements. It is apparent that the weight transmitted to the sacrum by the superimposed part of

the vertebral column will tend to cause its upper end to rotate forwards and its lower end with the coccyx to rotate backwards (*fig. 336*). Ligaments are so disposed as to resist this tendency. Further, the articular surfaces of the sacrum are farther apart in front than behind; so, the sacrum behaves not as a keystone, but as the reverse of a keystone, and sacral tuberosities. It lies above and behind the joint. (2) *The Short and Long Posterior Sacro-iliac Ligaments* unite the 1st and 2nd, and the 3rd and 4th transverse tubercles of the sacrum respectively to the posterior superior iliac spine. (3) *The Ilio-lumbar Ligament*, described with the lumbo-sacral joint, assists in preventing forward rotation.

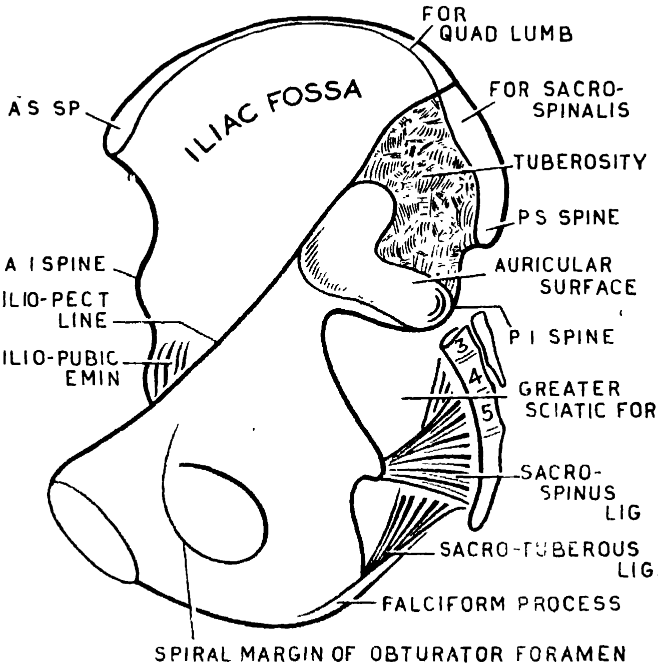


FIG. 335 Inner surface of hip bone.

tends therefore to sink forwards into the pelvis. As it does so, the posterior ligaments become taut and draw the ilia closer together with the result that the interlocking ridge and furrow engage more closely. Here is an automatic locking device (*fig. 337*).

THE LIGAMENTS RESISTING FORWARD ROTATION OF THE UPPER END OF THE SACRUM are: (1) *The Interosseous Sacro-iliac Ligament*, which is the strongest ligament in the body, unites the iliac and

THE LIGAMENTS RESISTING BACKWARD ROTATION OF THE LOWER END OF THE SACRUM are the sacro-tuberous and sacro-spinous ligaments. The one passes from the tuberosity of the ischium, the other from the spine of the ischium to the available parts of the side of the sacrum and coccyx, that is to the lateral border of the sacrum and coccyx below the articular facet. (1) *The Sacro-tuberous Ligament*, retarded as the divorced tendon of the Biceps Cruris, is a broad

band that extends from an impression on the medial part of the tuber ischii to the free part of the side of the sacrum and coccyx and to the adjacent part of the dorsum (*fig. 338*). The medial border extends as a falciform crest along the sharp medial border of the tuber ischii;

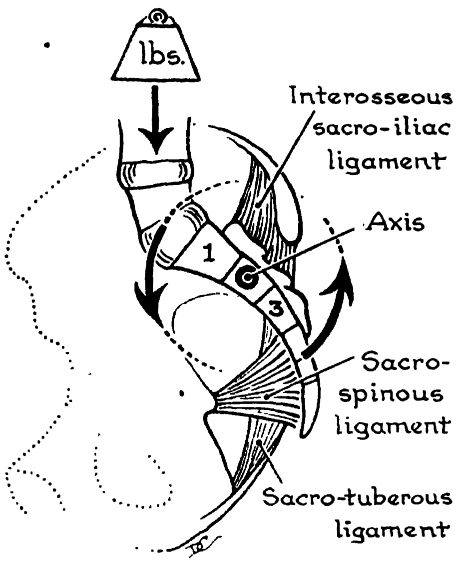


FIG. 336. Ligaments resisting rotation of the sacrum.

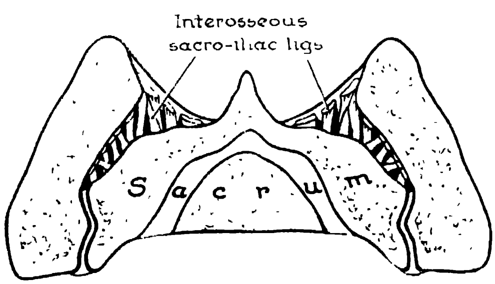


FIG. 337. The sacro-iliac joint on transverse section. Note the locking device.

it is continuous with the obturator fascia. The lateral part continues to the posterior (inferior and superior) spines of the ilium; it affords attachment to the Gluteus Maximus. (2) *The Sacro-spinous Ligament* is a triangular sheet sandwiched between the sacro-tuberous ligament and the Coccygeus. Co-extensive with the Coccygeus and regarded as its degenerated posterior lamina, it extends from the ischial spine to the side of the free parts of the sacrum and coccyx.

The sacro-tuberous and the sacro-spinous ligaments convert the greater and lesser sciatic notches into foramina. They are no doubt responsible for the curvature of sacrum, which is a characteristic of man, who alone walks erect.

The anterior part of the joint cavity is closed by a strong fibrous capsule called the *anterior sacro-iliac ligament.*

MOVEMENTS. In a fresh specimen it is easily demonstrated (1) that the sacrum can rotate backwards and forwards between the hip bones; and, after division of the disc and ligaments of the symphysis pubis, (2) that the pubic bones easily spread half-an-inch and (3) allow the hip bones to rock fairly freely on the sacrum.

During pregnancy the ligaments of the pelvis are relaxed and rotation is more free.

ANTERIOR RELATIONS. *In the true pelvis*, the lumbo-sacral trunk, the superior gluteal a., and the 1st sacral nerve are in contact with the capsule. *In the false pelvis*, the Iliacus and Psoas are in contact, and the obturator n. is a quarter of an inch removed (*fig. 326*).

SURFACE ANATOMY. The ilium articulates with the first three sacral vertebrae; and, naturally, the centre of the articulation is at the level of the 2nd. This is not readily identified, but the posterior superior iliac spine, which lies at the level of the 2nd sacral vertebra is readily palpated. The joint lies lateral to this (*pp. 393–394 and fig. 394*).

DEVELOPMENT AND VARIATIONS. The sacro-iliac joint and the symphysis pubis do not develop, like other joints, as clefts in a continuous rod of condensed mesenchyme but by the coming into apposition

of the ilium and sacrum posteriorly and of the pubic bones of opposite sides anteriorly. The auricular surface of the sacrum is usually covered with hyaline cartilage, that of the ilium with fibrocartilage, and between them there is a joint cavity which is present before birth (Schunke).

Accessory articular facets, 1 to 2 cm. in diameter, are commonly found between the opposed tuberosities of the sacrum and ilium.

urinary bladder and the urethra constitute the unpaired, median parts of the system. They will be studied now, and with them the pelvic portions of the ureters will be considered more fully.

The Urinary Bladder. The empty and contracted urinary bladder, shaped not unlike the forepart of a ship, has four surfaces and four angles (*fig. 339*). To each of the *four angles* a duct is attached: the *urachus* to the anterior angle or apex, the *right and left ureters* to the postero-

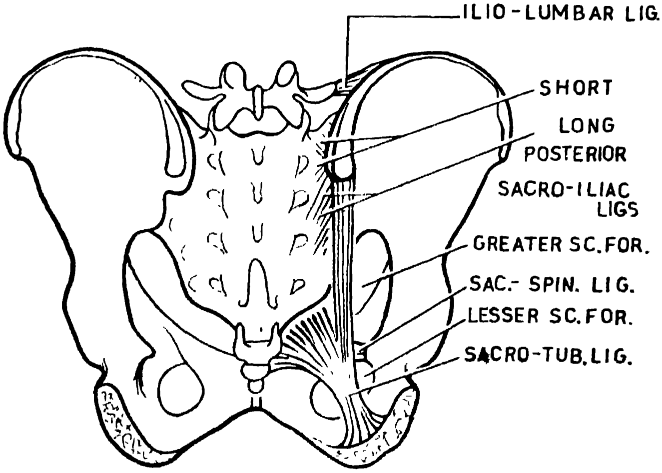


FIG 338 The pelvis and the ligaments of the pelvis (posterior view).

Synostosis, involving the anterior part of the capsule (anterior sacro-iliac lig.) occurs with some frequency after middle life, particularly in males.

The scapula does not articulate with the vertebral column; hence, there is no homologous articulation in the upper limb.

THE GENITO-URINARY SYSTEM

(continued)

The kidneys and ureters constitute the paired, bilateral parts of the urinary system. They have been studied. The

lateral angles, and the *urethra* to the inferior angle or neck. The four surfaces are: the superior, the sides or infero-lateral, and the base or infero-posterior. Each of the four surfaces is triangular for each is bounded by the rounded borders that connect three of the angles. *The superior surface* and half-an-inch of the infero-posterior surface are the only parts covered with peritoneum. The superior surface is bounded by the rounded borders that connect the ureters to each other and to the urachus. It supports pelvic colon and ileum. Now, the urinary bladder like certain other organs,

notably the lungs, the liver, the spleen, and the parotid salivary gland, owes its shape largely to the structures in contact with it. That this is so will be appreciated when it is pointed out that at birth the bladder is an abdominal organ, fusiform in shape, lying in the extraperitoneal tissue of the anterior abdominal wall; and, that only by about the 6th year has the pelvis enlarged sufficiently to allow it to sink to its permanent pelvic position and tetrahedral shape.

The bed or mould in which the bladder lies is formed by the pubic bone, the

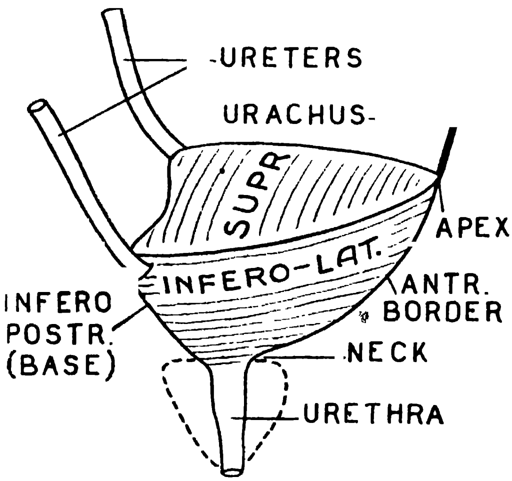


FIG. 339. The 4 surfaces, 4 angles, and 4 ducts of the urinary bladder

Obturator Internus, and the Levator Ani on each side, and by the rectum behind; hence the infero-lateral and infero-posterior surfaces (*figs. 324, 340*). The entire organ is enveloped in areolar tissue, the *vesical fascia.* A dense plexus of veins, the *vesical plexus,* lies in this fascia on the side of the bladder, clings to the bladder, and separates it from the retro-pubic space. The base or *infero-posterior surface* of the bladder is separated from the rectum by the seminal vesicles and ampullated ends of the vasa deferentia, which are enclosed between the two layers of recto-vesical fascia; above these the peritoneum of the recto-vesical fossa separates the upper half-inch of the bladder from the rectum (*figs. 319, 325*).

It is not usually appreciated that the bladder rests upon the rectum as though on a shelf, due to the fact that the lower part of the rectum takes a course that approaches the horizontal.

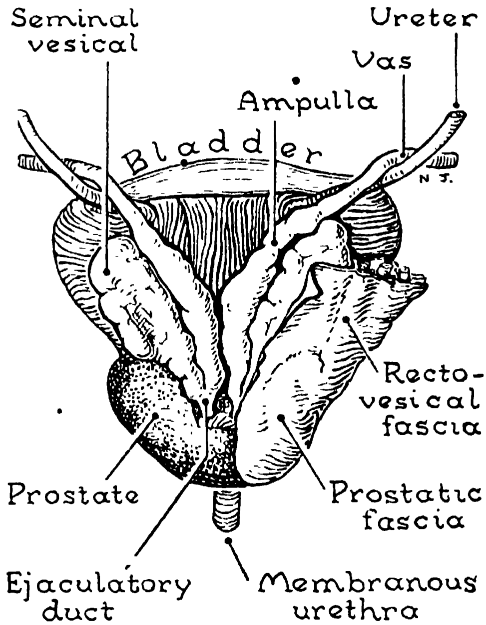


FIG. 340. The posterior relations of the bladder.

The Pelvic Portion of the Ureter. Each ureter enters the pelvis at the bifurcation of the common iliac artery and descends immediately in front of the internal iliac artery. It lies subperitoneally, save where crossed by the vas deferens an inch or less from the bladder, and it crosses medial to the structures on the side wall of the pelvis; these are: the external iliac a. and v., the obliterated umbilical a., the obturator n., a., and v. and the inferior vesical a. and v. Before passing through the bladder wall,

it crosses the apex of the seminal vesicle and is there surrounded by a leash of vesical veins (*figs. 321, 322*).

The Interior of the Bladder is best exposed by cutting a V-shaped flap in its upper surface and raising it like the lid of a box. The mucous membrane is seen to lie in folds, except over the trigone where it is smooth. *The trigone* is an equilateral triangle on the interior of the base of the bladder (*fig. 341*). Its sides are an inch or so long; the two ureters and the urethra open at its angles. The turally with the bladder at the postero-lateral angles, but penetrate its wall obliquely to open an inch apart at the base of the trigone. If a transverse incision is made through the mucous coat of the bladder at the upper border of the inter-ureteric torus, and carried laterally through the bladder wall to the postero-lateral angles, the ureters can be eased, with the aid of the handle of a knife, free from their areolar bed. Muscle fibers radiate from the ureters and blend with the muscle of the trigone.

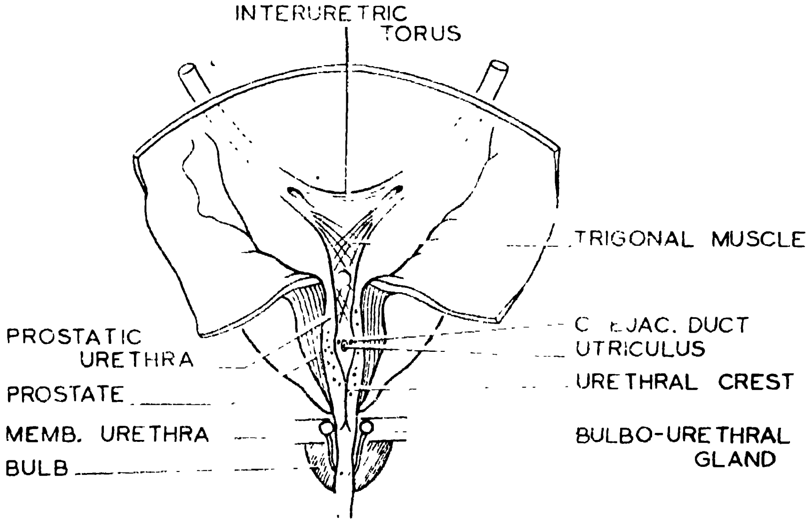


FIG. 311. The trigone of the bladder and the prostatic urethra

internal orifice of the urethra lies at the lowest point of the bladder and, therefore, is situated advantageously for drainage. A pencil can be pushed into it. The orifice of each ureter is guarded by a fold of mucous membrane and is collapsed. A ridge, the *interureteric torus*, connects the two ureters at the upper border of the trigone. An elevation, the *uvula*, overlying the middle lobe of the prostate, is sometimes to be seen at the apex of the trigone behind the urethral orifice.

The ureters are not continuous struc-

The Trigonal Muscle is a submucous sheet distinct from the muscle wall proper. It is continuous with the muscle wall of the ureters above; its apex descends in the posterior wall of the urethra to the utriculus. This trigonal area of the bladder and urethra is derived from the Wolffian or mesonephric ducts. Together with the ureters, it can be separated from the underlying muscle, if the bladder is well preserved. It is supplied by the hypogastric plexus (L. 1, 2, 3).

Though 500 cc. can be injected into the

bladder without causing discomfort, urine is usually voided when little more than half this volume has accumulated; the exact volume depending largely on acquired habit.

As the bladder fills, the trigone enlarges but little; so, the three orifices are not displaced, but the rest of the bladder stretches. When the fundus reaches the level of the umbilicus, the peritoneum is stripped from the anterior abdominal wall for one to two inches above the symphysis pubis; and, from the sides of the bladder, it is reflected on to the side walls of the pelvis at the level of the obliterated umbilical arteries; and the extent of the retro-pubic space is, of course, increased.

Vessels and Nerves of the Bladder.

Arteries: superior and inferior vesical.

Veins pass to the vesical plexus and thence to the internal iliac veins.

Lymph vessels (p. 369).

Nerves. Pelvic splanchnic nn. and hypogastric plexus (*fig. 48; pp. 63 and 367*).

The Male Urethra (Urethra Virilis). The male urethra is a fibro-elastic tube, 8 inches long (*fig. 342*). It is divided by the superior and the inferior fascia of the urogenital diaphragm into three parts: *prostatic, membranous,* and *spongy.* The part above the superior fascia traverses the prostate; the part between the two fasciae has no covering; the part beyond the inferior fascia or perineal membrane traverses the corpus spongiosum penis.

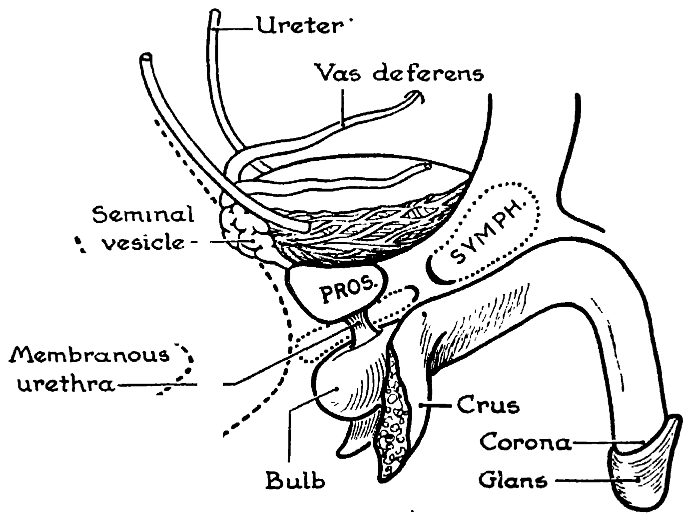


FIG. 342. The lower parts of the genital and urinary tracts and their relations.

THE PROSTATIC URETHRA (*fig. 341*) is the widest and most dilatable part of the urethra. It runs almost vertically and is an inch or more long. In shape it is fusiform; and on transverse section it is crescentic, owing to the presence of a prominent vertical ridge on the posterior wall, called the *urethral crest.* The gutter on each side of the crest is called the *prostatic sinus.* The urethral crest rises to a summit, the *colliculus,* and bifurcates below as it fades away. Opening on to the colliculus is a diverticulum, the *prostatic utricle,* up which a probe can be passed for half-an-inch into the substance of the prostate; and on to its lips open the much finer orifices of the right and the

left *ejaculatory duct.* On to the floor of each prostatic sinus several dozen *prostatic ducts* open.

THE MEMBRANOUS URETHRA passes through the urogenital diaphragm and its two fasciae an inch from the symphysis pubis. It is half-an-inch long and has no proper clothing. Behind it on each side lies a bulbo-urethral gland of Cowper. The circular fibers of the diaphragm—called the *Sphincter Urethrae* or Compressor Urethrae, sometimes called "the shut-off muscle"—form for it a sphincter of voluntary muscle supplied by the perineal branch of the internal pudendal nerve. Like the Sphincter Ani Externus, also supplied by the pudendal nerve, it is in constant contraction.

THE SPONGY OR PENILE URETHRA traverses the bulb, body, and glans of the corpus spongiosum penis. It enters the bulb on its upper surface and ends near the lower part of the apex of the glans at the external urethral orifice. Its lumen is dilated both in the bulb and in the glans. The dilatation in the glans is known as the terminal (navicular) fossa. (*Fig. 316.*)

Axioms. (a) The external urethral orifice is commonly the narrowest part of the urethra. In this it resembles other ducts, such as the ureters, ejaculatory ducts, common bile and pancreatic ducts, and the ducts of the parotid and submandibular salivary glands. A small renal calculus after leaving the kidney may stick at the vesical orifice of the ureter, or, having passed, it may yet stick at the external urethral orifice. (b) Further, though the membranous and spongy urethrae are lined with stratified columnar epithelium, the terminal or navicular fossa is lined with stratified squamous epithelium, as are other orifices opening on to the skin surface such as, the conjunctiva, nostrils, mouth, mammary ducts, sebaceous ducts, (but not the sweat ducts), anal canal, and vagina (c) Again, because the male urethra conveys the secretions of the kidneys, testes. and various other glands (viz., prostate. seminal vesicles, ampullae of the vasa deferentia, bulbo-urethral and urethral glands), it belongs to the genital as well as to the urinary system.

Palpation. A catheter passed into the bladder can be palpated in the *spongy urethra* from the under surface of the penis, in the *membranous urethra* from the perineum, and in the *prostatic urethra* per rectum.

Nerve supply (p. 367 and fig. 48)

The Structure of the Urinary Tract.

Epithelium. The calyces, pelvis of the ureter, ureter, bladder, and prostatic urethra are lined with transitional epithelium, 3-4 cells thick; that of the empty bladder being 6-8 cells thick. It is elastic. The epithelium is stratified columnar in the membranous and spongy urethrae, except with the terminal fossa where it is stratified squamous. The mucous surface is neither absorptive nor secretory like that of the intestine, which is lined with a single layer of cells, nor is it subjected to friction and rough treatment like the skin and the mucous membrane of the mouth and esophagus which have a stratified squamous epithelium.

The Tunica Propria is thick and loose in the ureter and bladder, and it falls into folds when they are empty. It has no tunica muscularis mucosae—such is restricted to the alimentary passage beyond the pharynx. Because the urinary tract is not normally exposed to infection from without like the alimentary and respiratory passages, the tunica propria is not permeated with diffuse lymphoid tissue.

Muscle. The urinary tract has both an inner longitudinal and an outer circu-

lar coat of muscle. At the calyces the fibers are circular and have been described as having a "milking" action on the renal papillae. The lower part of the ureter and the bladder have an additional outer longitudinal coat; the layers are interwoven in the bladder, the innermost being somewhat reticular. Fibers from the longitudinal and circular muscle coats loop from behind forwards round the front and sides of the upper part of the prostatic urethra. These slings are known as the *Sphincter Vesicae* (Internal Sphincter).

The circular and longitudinal fibers in the urethra are not numerous.

The intramural part of the ureter has longitudinal fibers, but no circular ones. Of these some join their fellow in the interureteric torus, others radiate into the trigonal muscle.

Mucous cells, singly and in clusters lining recesses (lacunae urethrales), as well as in branching outpouchings (glands of Littré) in the tunica propria, occur especially on the dorsum of the anterior two-thirds of the spongy urethra. They may extend to the neck of the bladder.

Common Direction. The mouths of all ducts and tubes opening into the urethra open forwards, in the direction in which the urine flows. Hence, urine does not enter them during micturition.

The Genital System of the Male. *The external parts* are—the penis, scrotum, testes, epididymes, and parts of the vasa deferentia. They have been studied. *The internal parts* are—the remainder of the vasa deferentia, the seminal vesicles, the ejaculatory ducts, and the prostate. They will be dealt with now.

The Prostate Gland surrounds the urethra between the bladder and the u. g. diaphragm. It occupies the same bed as the bladder and it resembles the bladder in shape, its surfaces being—superior, infero-lateral, and infero-posterior. Of these, the superior faces the bladder; the infero-lateral lie on the Levatores Ani; and the infero-posterior lies on the rectum. Its apex, from which the urethra emerges, abuts against the upper fascia of the diaphragm between the anterior borders of the Levatores Ani.

The prostate is encased in a strong envelope of pelvic fascia, which is continuous below with the upper fascia of u. g. diaphragm, and which is anchored to

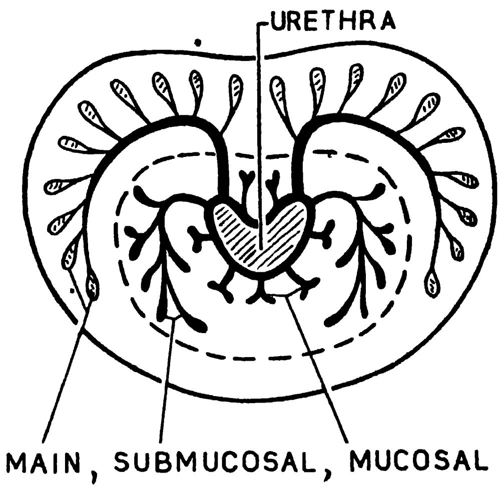


FIG. 343. Prostate in transverse section showing three concentric groups of tubules (schematic). (After Adrion.)

the pubes by the pubo-prostatic (-vesical) ligaments. The *prostatic fascia* is distinct from the outermost part of the gland proper, which is called the *capsule of the prostate* (*figs. 325, 324*). On each side of the prostate the capsule is separated from the fascia by a cavernous plexus, called the *prostatic* (pudendal) *plexus of veins.* This plexus receives the deep dorsal vein of the penis in front, communicates with the vesical plexus above, and drains into the internal iliac veins behind. The posterior part of the

prostatic fascia forms a broad strong sheet, called by the surgeon the *fascia of Denonvilliers*. It is easily separated from the loose rectal fascia behind it.

The prostate can be palpated per rectum and exposed bloodlessly from the perineum (pp. 315–316).

The urethra passes vertically through the forepart of the prostate; the prostatic utricle projects into the hinder part, and the ejaculatory ducts pierce its upper

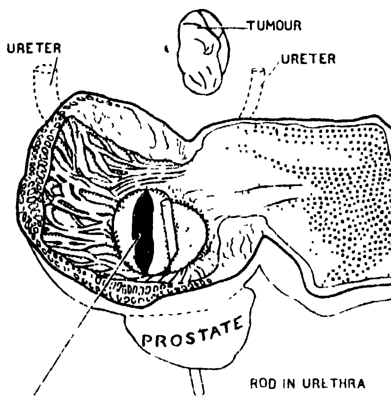


FIG. 341 Prostatic tumour. In dissecting room subjects simple tumours of the prostate, which may obstruct the urethra with consequent dilatation of the bladder and ureters, are not uncommon. Such tumours may be shelled out of the prostate with the aid of the rounded end of the handle of a knife, after incising the overlying mucous membrane of the bladder.

surface and open on to the lips of the utricle.

STRUCTURE. The prostate is a modified portion of the urethral wall. In composition it is ½ glandular, ¼ involuntary muscle, and ¼ fibrous tissue. The glands are arranged in 3 concentric groups (*fig. 343*). The innermost or *mucosal* are short and simple. They open all round the urethra above the level of the colliculus. "All hypertrophies of the prostate arise from these mucosal or suburethral glands" (Young) (*fig. 344*). The intermediate or *submucosal* glands open into the prostatic sinus at the level of the colliculus. The outermost or *prostatic glands proper* are long and branching. They envelop the other two groups, except in front where those of opposite sides are joined by a non-glandular isthmus. Their ducts open into the prostatic sinus.

The Vas (Ductus) Deferens or spermatic duct has a course in the scrotum, in the inguinal canal, on the side wall of the pelvis, and between the bladder and rectum. It is as long as a femur or a spinal cord, that is, 18 inches. Before birth, it is subperitoneal throughout, for in the scrotum and inguinal canal, where it is a constituent of the spermatic cord, the funicular process (formerly the processus vaginalis peritonei) accompanies it (*figs. 324, 312*). In the abdomen and pelvis the vas remains strictly subperitoneal as far as the base of the bladder, and between the bladder and rectum it ceases to be subperitoneal after about the sixth year, when the lowest part of the recto-vesical fossa, which formerly descended to the apex of the prostate, is obliterated (*fig. 253*).

With these facts in your mind, note that the vas, after turning round the lateral side of the inferior epigastric a., crosses the external iliac a. and v., the obturator n., a., and v., the obliterated umbilical a., and the ureter. Where the vas lies between the two layers of recto-vesical fascia, medial to the seminal vesicle, it is ampullated, thin-walled, and easily torn. Here it is separated from its fellow by a triangular area bounded above by the peritoneum of the recto-vesical fossa. This ***triangular area at the base of the bladder*** is not to be confused with the trigone of the bladder.

The Seminal Vesicles. Each vesicle is a tortuous, branching diverticulum developed from the ampullated end of the

vas deferens, and possessing much the same histological structure. (*Fig. 346.*) It lies between the two delicate layers of

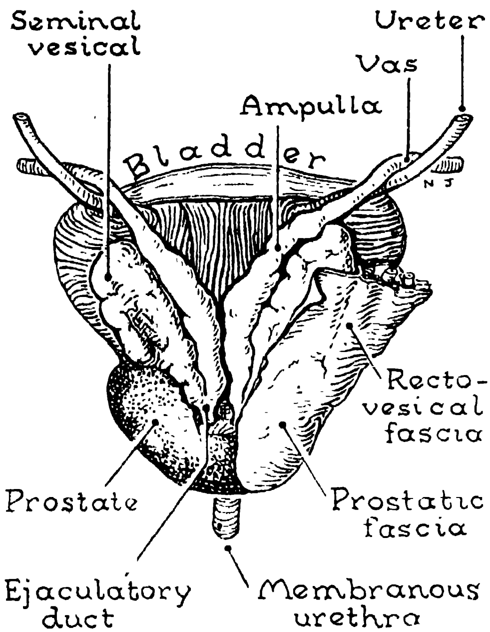


FIG. 345 The seminal vesicles and the vasa.

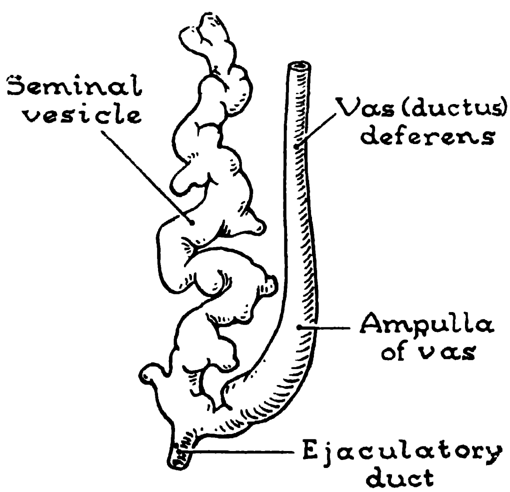


FIG. 346. The seminal vesicle unravelled.

the rectovesical fascia; i.e., in the primitive uro-rectal septum (*fig. 307*). *In front* is the bladder; *behind* is the cylindrical rectum on which it is moulded; *medial* to it is the vas of which it is an outgrowth; *above* it is capped with peritoneum; and laterally it is separated from the Levator Ani by numerous vesical vessels. The vesicles of the two sides form a crescent that partly embraces the rectum. The vesicles, prostate, and bulbourethral glands each add a distinctive secretion to the semen. Storing spermatozoa, formerly thought to be a function of the vesicles, is now known to take place in the epididymis. Indeed, seminal vesicles are absent in dogs and other carnivora.

The Ejaculatory Duct is the duct common to the vas and the seminal vesicle. It has the diameter of the lead of a pencil. It is easily torn away from the prostate, the upper half of which it pierces obliquely to open beside the prostatic utricle.

Vessels and Nerves. *The inferior vesical* and *middle rectal (hemorrhoidal) aa.* supply the base and sides of the bladder, the front of the lower part of the rectum, and the structures in between (viz., the prostate, seminal vesicles, ampullae of the vasa, and ends of the ureters). The artery to the vas deferens springs from either the inferior or the superior vesical artery.

Nerves. (See page 63).

THE INTESTINUM RECTUM AND ANAL CANAL

The intestinum rectum and anal canal are the terminal parts of the large intestine. The rectum begins where the colon ceases to have a mesentery, which is in front of the 3rd piece of the sacrum, and it is about five inches long. The rectum continues the curvature of the sacrum and coccyx downwards and forwards for an inch and a half beyond the coccyx, and there, at the apex of the prostate, makes a right-angled bend and becomes the anal canal. The anal canal

passes downwards and backwards for an inch or more to its orifice, the *anus*.

The lower third of the rectum is not covered with peritoneum; the middle third is covered in front; the upper third is covered in front and on the discs. The distance from the skin surface to the peritoneal cavity (i.e., to the recto-vesical fossa), measured in front of the anal canal and rectum, is 3-4 inches; measured behind them (i.e., to the para-rectal fossa) it is 5-6 inches (*fig. 319*).

The rectum in man is not straight as its name would imply; it has the antero-posterior curvature just described; it has also 3 lateral curvatures: thus, at the bottom of the recto-vesical fossa, 3-4 inches from the anus, the right wall is indented with the result that a transverse fold or shelf projects into the lumen; and similar but less pronounced indentations from the left occur about an inch below and above this. The shelves within the gut are the *plicae transversae* (*fig. 347*). They consist of mucous membrane and circular muscle. Their form is maintained by the prolongations of the three taeniae coli, of which the postero-medial spreads out on the back of the rectum, while the anterior and postero-lateral join and spread out on the front. Instruments introduced into the rectum may catch on the plicae. The dilated part of the rectum below the recto-vesical fossa is the *ampulla*.

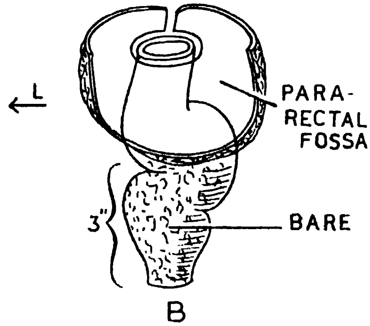


FIG. 317. The lateral flexures of the intestinum rectum (front view)

The upper part of the anal canal possesses 5-10 permanent longitudinal folds of mucous membrane, the *anal columns* of Morgagni, whose lower ends are united by semilunar folds, the *anal valves* of Ball. They likely are residual parts of the cloacal membrane. Above the anal valves the gut is lined with columnar epithelium containing goblet cells derived from the endoderm; below, with stratified squamous epithelium derived from the ectoderm.

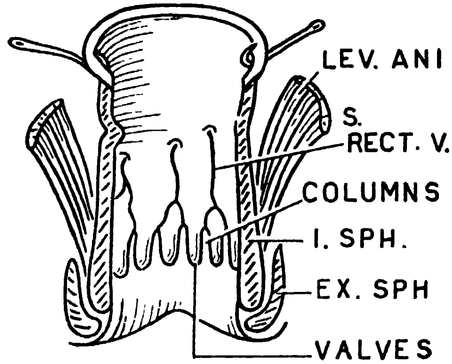


FIG 318. The interior of the rectum and anal canal

Arteries. The superior, middle, and inferior rectal or haemorrhoidal arteries supply the rectum and anal canal, making 5 arteries in all—for the superior a. is unpaired. *The superior rectal a.* is the continuation of the inferior mesenteric a. It begins in front of the left common iliac a., and there lies medial to its own vein and to the ureter. It descends in the vertical part of the root of the pelvic meso-colon to the beginning of the rectum where it divides into a right and a left branch. The lowest left colic (sigmoid) a. commonly springs from the stem of the superior rectal a. so also do several twigs that supply adjacent parts of the colon and

rectum. As the right and left branches descend, they give off obliquely encircling branches which pass towards the front of the gut. Branches, given off irregularly from these, pierce the muscle coat, ramify in the submucosa, and descend in the mucous membrane of the anal columns (*fig. 348*).

The middle rectal a. is a small and inconstant branch of the internal iliac a. It passes to the side of the rectum and makes variable anastomoses with the superior and inferior rectal aa. and with the prostatic, vesical, (and vaginal) aa.

The inferior rectal a. is a branch of the internal pudendal a. It supplies the musculature of the anus and anastomoses by fine twigs with the middle rectal a.

The median sacral a. sends negligible twigs to the back of the rectum.

Veins. The superior, middle, and inferior rectal or haemorrhoidal veins accompany their arteries and drain corresponding parts of the rectum and anal canal. The superior vein becomes the inferior mesenteric vein and, therefore, belongs to the portal system. The middle and inferior veins are paired and belong to the caval system. *The superior vein* begins in the anal columns. It has extensive mucous and submucous plexuses, and it receives branches from the perirectal tissues. *The middle rectal vein* is a much more important vessel than the corresponding artery. It drains the rectum above the Internal Sphincter and communicates both submucously and perimuscularly with the inferior rectal vein, and it makes free anastomoses submucously with the superior rectal vein. Its branches communicate with the prostatic (vaginal and uterine) plexus. It is the chief link between the portal and caval systems, and it ends in the internal iliac vein. *The inferior vein* drains the anus and Sphincter Ani Externus.

Lymph Vessels. See page 369.

Nerves. See page 367.

Relations. The rectum extends from the 3rd piece of the sacrum to a point an inch and a half beyond the coccyx (*fig. 349*). It is as broad as 2 or 3 fingers and much broader than the coccyx; so, the rectum and anal canal have *behind* them: 3 pieces of sacrum, the coccyx, the ano-coccygeal body; Piriformis, Coccygeus, Levator Ani; the median sacral a. and v., the sympathetic trunks and ganglion impar, parts of 3 sacral and 1 coccygeal nerve, the lateral sacral vessels and in the rectal fascia are branches of the superior rectal vessels and lymph glands. (*fig. 352*). *On each side* are: the pararectal fossa containing pelvic colon or ileum; the middle rectal vessels, the pelvic splanchnic and "presacral" nerves, the Levator Ani, and the ischiorectal fossa. *In front* are: the bladder separated by recto-vesical fossa, 4 layers of fascia, seminal vesicles, and ampullae of the vasa; the prostate separated by 2 layers of fascia, and the perineal body (*fig. 342*). Strands of involuntary muscle, the *recto-urethral muscle*, connect the

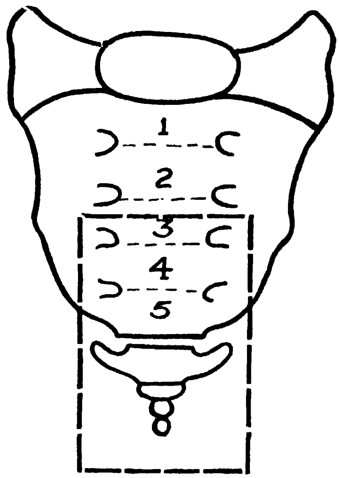


FIG. 349. The parts of the sacrum and coccyx covered by the rectum (*see fig. 326*).

ano-rectal junction to the Sphincter Urethrae (*fig. 325*).

THE VESSELS AND NERVES OF THE PELVIS

The **Arteries of the Pelvis** are the median sacral, the superior rectal (haemorrhoidal), and the internal iliac arteries.

The Median Sacral Artery is smaller than a lumbar artery, nevertheless, it is the continuation of the aorta and, like the aorta, it clings to the vertebral column. It descends from vertebra L. 4 to the coccyx, and therefore passes behind the left common iliac vein, (superior) hypogastric plexus, and rectum. It sends twigs to the neighboring structures. As the continuation of the aorta, it should give off the 5th lumbar and the sacral arteries, but it does not—it is too small.

Its companion vein ends in the left common iliac vein.

The Superior Rectal (Haemorrhoidal) Artery is the continuation of the inferior mesenteric artery. It is described with the rectum on page 311.

The Internal Iliac (Hypogastric) Artery (*fig. 351*) takes origin from the common iliac artery one-third of the way, i.e., two inches, along the line joining the aortic bifurcation to the midinguinal point. It ends about the level of the pelvic brim by dividing into an anterior and a posterior division. It descends subperitoneally and crosses medial to the external iliac vein, the Psoas, and the obturator nerve. In front of it runs the ureter; behind it lies its vein.

The branches of the internal iliac artery arise erratically. Usually the superior gluteal and the two somatic segmental branches come from the posterior division; the others from the anterior. They may be grouped thus:

1. The obliterated umbilical and other visceral branches:
   Superior vesical *Inferior vesical*
   Middle rectal

(also, *Uterine* and *Vaginal* in the female)

2. Branches to the limb and perineum:
   Superior gluteal *Inferior gluteal*
   Obturator *Internal pudendal*
3. Somatic segmental branches:
   Ilio-lumbar *Lateral sacral*

1. **The Visceral Branches** supply the bladder, the internal genital organs behind the bladder, and they send a twig to the rectum. They are:

(a) *The obliterated umbilical (hypogastric) artery:* In prenatal life the internal iliac artery of each side passed through the umbilical cord to supply the allantois, which is the endodermal prolongation of the anterior or bladder portion of the cloaca. When the placenta superseded the allantois, the internal iliac artery became the placental or umbilical artery. At birth the umbilical cord was severed and discarded with the placenta, whereupon the umbilical artery became obliterated as far back as the branches (superior vesical) to the fore part of the cloaca now called the bladder. This obliterated end part of the artery has already been observed ascending extraperitoneally on the anterior abdominal wall to the umbilicus, between the urachus medially and the inferior epigastric artery laterally (*figs. 39, 345*). The umbilical artery is, therefore, a visceral artery, and it clings to the peritoneum on the side wall of the pelvis, above the level of the bladder. The only structures crossing medial to it are the ureter and the vas deferens. *The superior vesical arteries* are 2 or 3 branches that pass from the pervious part of the umbilical artery to the upper surface of the bladder.

(b) *The inferior vesical artery* and (c)

the middle rectal (*hemorrhoidal*) *artery* run in the leash of veins that form the posterior limit of the retro-pubic space, and that pass from the postero-lateral border of the bladder and prostate to the side wall of the pelvis where they end in the internal iliac vein. These two arteries supply the sides and base of the bladder, the prostate, seminal vesical, ampulla of the vas, and the end of the ureter, and they supply twigs to the front of the rectum and give off the deferent artery.

2. The Branches to the Limb and Perineum leave the pelvis through the greater sciatic and obturator foramina, thus: (a) *the superior gluteal artery*, which is much the largest branch of the internal iliac artery, crosses in front of the sacro-iliac joint and hugs the iliac bone, making a U-shaped turn round the angle of the greater sciatic notch into the gluteal region. Its vein and the superior gluteal nerve accompany it. (*Fig. 326.*)

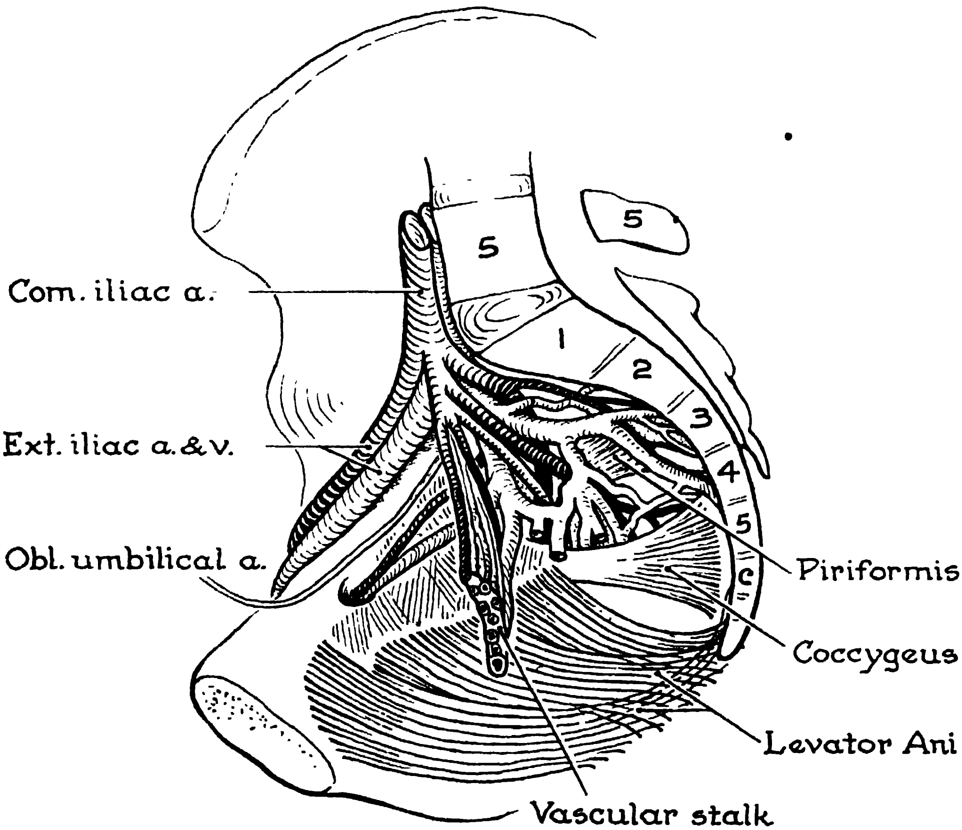


FIG. 350. The blood vessels of the pelvis. The vascular stalk to the pelvic viscera limits the retro-pubic space posteriorly.

(b) *The inferior gluteal artery* and (c) *the internal pudendal artery* descend in front of the sacral plexus and pass between the borders of the Piriformis and Coccygeus into the gluteal region. There the pudendal artery, which is the smaller and more anterior, crosses the ischial spine and returns to the pelvis

through the lesser sciatic foramen in company of its own nerve and the nerve to the Obturator Internus.

As mentioned with the sacral plexus, the superior gluteal a. passes medial to the lumbo-sacral trunk (sometimes lateral to it). The inferior gluteal a. passes between the (1st and 2nd) or 2nd and 3rd sacral nerves, and it may form a common stem with the i. pudendal a.

(d) *The obturator artery* runs forwards on the side wall of the pelvis to the obturator foramen. It lies between its nerve and vein. The obturator and inferior epigastric arteries both supply branches to the back of the pubis. These branches anastomose, and the anastomotic channel is commonly (35 per cent) so "abnormally" large that the obturator artery derives its blood from the epigastric artery and only slightly, if at all, from the internal iliac artery. This is known as an *abnormal obturator artery.*

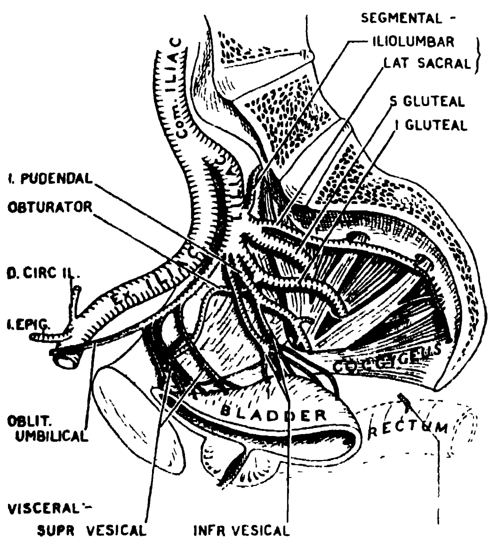


FIG. 351. The internal iliac artery and its branches.

The obturator vein likewise is commonly abnormal.

3. **The Somatic Segmental Branches** (i.e., to the body wall) are in series with the intercostal and lumbar arteries and, therefore, should arise from the continuation of the aorta, which is the median sacral artery. However, they generally arise from the posterior division of the internal iliac artery. (a) *The ilio-lumbar artery* is the somatic artery of the 5th lumbar segment. It ascends and crosses the ala of the sacrum between the lumbo-sacral trunk and the obturator nerve, and divides into iliac and lumbar branches. The iliac branches anastomose in the iliac fossa with the deep circumflex iliac and adjacent arteries. The lumbar branch supplies adjacent muscles and sends a spinal branch through the 5th intervertebral foramen. (b) *The lateral sacral artery* descends lateral to the anterior sacral foramina and in front of the roots of the sacral plexus. It sends spinal branches with the nerves into the anterior sacral foramina and twigs from these appear on the back through the posterior sacral foramina.

The Veins of the Pelvis (*fig. 350*). The pelvic viscera may be said to lie within a basket woven out of large thin-walled veins among which the arteries thread their way. The basket is divided into vesical, prostatic (or uterine and vaginal), and rectal venous plexuses, which drain largely into the internal iliac vein, but partly via the superior rectal (haemorrhoidal) vein into the inferior mesenteric vein and so to the portal vein. In the female, the uterine vein communicates with the pampiniform plexus of ovarian veins. The middle rectal (haemorrhoidal) vein is relatively large. It emerges from the lower part of the side of the rectum and passes to the internal iliac vein. It anastomoses with the superior and inferior rectal veins and, therefore, belongs to the accessory

portal system (p. 252). It also anastomoses with the prostatic plexus of veins.

The Sacral and Coccygeal Nerve Plexuses. The lumbar, sacral, and coccygeal plexuses are derived from the anterior rami of the spinal nerves shown in table 14.

TABLE 14

ANTERIOR RAMI OF	Th.	L.	S.	C.
Lumbar plexus	12,	1, 2, 3, 4		
Sacral plexus	..	... 4, 5,	1, 2, 3, 4	
Coccygeal plexus	...	....	...... 4, 5,	1

Note that rami L. 4 and S. 4 both contribute to two plexuses. Each does so by means of an upper and a lower branch.

Like all other anterior nerve rami, the roots of the sacral and coccygeal plexuses receive grey sympathetic rami communicantes, which they conduct to the blood vessels, sweat and sebaceous glands, and arrectores pilorum in their territory. No white sympathetic rami communicantes arise caudal to L. 3, but parasympathetic fibers, called the *pelvic splanchnic nerves*, pelvic autonomic nerves, or nervi erigentes, arise from the anterior rami of S. (2), 3 and 4 (*figs. 764, 766*).

The Sacral Plexus (*figs. 352, 353*). Of the six roots of the sacral plexus, L. 4 crosses and grooves the fifth lumbar transverse processes; L. 5 crosses and grooves the ala of the sacrum and joins with L. 4 near the pelvic brim to form the lumbo-sacral trunk; the upper 4 anterior sacral rami groove the lateral mass of the sacrum. The lumbo-sacral trunk and S. 1 join as they pass in front of the sacro-iliac joint, and they unite with S. 2, 3, and 4 in front of the Piriformis to form the sacral plexus. The plexus has many collateral branches and it ends as two terminal branches, the *sciatic* and *pudendal nerves*. The sacral plexus is placed in front of the Piriformis and outside the pelvic fascia—as you would expect—which separates it from the branches of the internal iliac artery and from the voluminous plexus of tributaries of the internal iliac vein.

Arteries Piercing the Plexus. Four branches of the internal iliac artery pierce the plexus, after first piercing the pelvic fascia, thus: the *ilio-lumbar a.* passes between L. 4 and 5, the *superior gluteal* a. between L. 5 and S. 1, the *inferior gluteal a.* between S. 2 and 3, and the

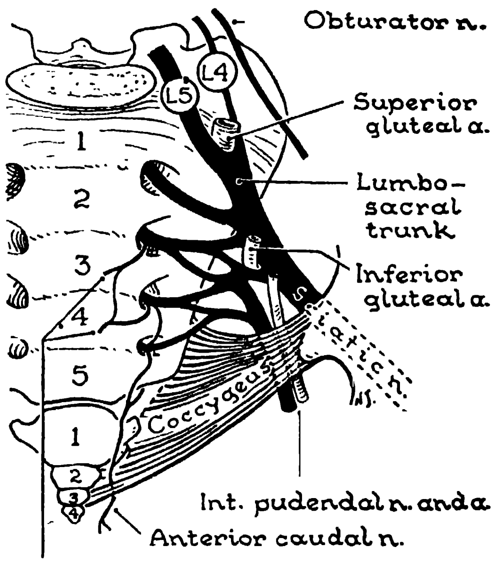


FIG. 352. The sacral plexus.

internal pudendal a. descends to the ischial spine between the sciatic and pudendal nerves. Commonly these four arteries are moved independently or together cranialwards: the ilio-lumbar a. then passes between the obturator n. and the descending branch of L. 4; the superior gluteal a. between the lumbo-sacral trunk and the upper border of the greater sciatic notch; and the inferior gluteal a. between S. 1 and 2. On the other hand, they may be moved caudalwards.

The Branches of the Sacral Plexus may be grouped thus:

1. Branches from roots of plexus:
   (a) *Muscular* (To Piriformis, Levator Ani, and Coccygeus.)
   (b) *The pelvic splanchnic nerve.*
2. Branches that pass through the greater sciatic foramen:
   (a) *2 terminal* (sciatic and pudendal.)
   (b) *5 collateral*
3. Branches that emulate the coccygeal plexus in piercing the structures attached to the side of the coccyx in order to become cutaneous:
   (a) *Perforating cutaneous of S. 2, 3*
   (b) *Perineal of S. 4*

1. THE BRANCHES ARISING FROM THE ROOTS OF THE SACRAL PLEXUS are, short twigs to the Piriformis (S. 1, 2), long branches that extend across and supply the Levator Ani and Coccygeus (S. 3, 4), and the pelvic splanchnic nerve (S. 2, 3, 4). Note that the pelvic splanchnic nerve and the pudendal nerve both spring from segments S. 2, 3, 4. The pudendal nerve is a mixed cerebro-spinal nerve. It supplies the muscles derived from the cloacal sphincter and the skin around the cloacal orifice. These muscles are voluntary and include the Sphincter Ani Externus and the Sphincter Urethrae. The pelvic splanchnic nerve is a mixed parasympathetic nerve. It supplies the involuntary muscles derived from the cloaca that cause the involuntary sphincters guarding the rectum and bladder (Sphincter Ani Internus and Sphincter Vesicae) to relax while the organs contract, and it is sensory to them. It also causes relaxation of the arteries of the erectile tissue of the penis or clitoris and thereby produces erection, hence the alternative name nervus erigens. (*fig. 306.*)

2. THE BRANCHES THAT PASS THROUGH THE GREATER SCIATIC FORAMEN enter the gluteal region and they should be studied with it. They are 7 in number, two being terminal and five collateral. The exact segments of origin of the collateral branches are unimportant, but they are given in order to make identification more easy.

The sciatic nerve is the largest nerve in the body and it forms the greatest part of the sacral plexus. It bears some resemblance to the forearm, palm, and outstretched digits of a limb; the digits being its five roots (L. 4, 5, S. 1, 2 and 3), the palm being the flat main mass of the plexus in front of the Piriformis, and the forearm being the rounded sciatic nerve that leaves the pelvis between the Piriformis and the ischial border of the greater sciatic notch. The sciatic nerve will later be seen to be two nerves loosely held together: one is the medial popliteal or tibial nerve; the other is the lateral popliteal or peroneal nerve—peroneal is Greek for the Latin word fibular.

The pudendal nerve (S. 2, 3, 4) already seen in the perineum, escapes between the Piriformis and Coccygeus just medial to the sciatic nerve.

TABLE 15
Branches of the Sacral Plexus

TERMINAL	COLLATERAL		
	From the back	From the front	From front and back
1. Sciatic 2. Pudendal	3. Superior Gluteal 4. Inferior Gluteal	5. N. to Quadratus Femoris 6. N. to Obturator Internus	7. Posterior cutaneous of the thigh

The superior gluteal nerve (L. 4, 5, 1) and the *inferior gluteal nerve* (L. 5, 1, 2) arise from the back of the plexus. The nerves to the *Quadratus Femoris* (L. 4, 5, 1) and *Obturator Internus* (L. 5, 1, 2) arise from the front of the plexus; the former descends in front of the sciatic nerve, the latter on the medial side of the sciatic nerve. The *posterior cutaneous nerve of the thigh* (S. 1, 2, 3) arises from the back and front of the plexus.

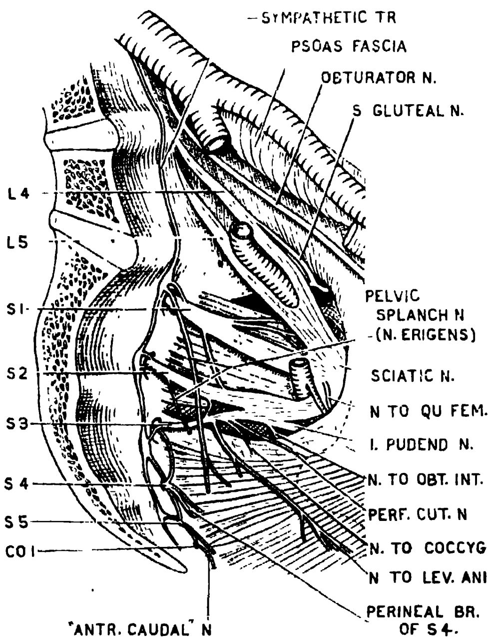


FIG. 353. The sacral and coccygeal nerve plexuses. (Left side.)

The superior gluteal nerve and its companion artery and vein escape from the pelvis above the Piriformis at the angle of the greater sciatic foramen. All other structures passing through the foramen pass below the Piriformis. The inferior gluteal nerve and the posterior cutaneous nerve of the thigh escape below the Piriformis and behind the sciatic nerve.

3. THE TWO BRANCHES THAT EMULATE THE TERMINAL BRANCH OF THE COCCYGEAL PLEXUS are the *perforating cutaneous branch* of S. 2 and 3 and the *perineal branch* of S. 4. These descend in front of the Coccygeus and then pass through it: thereafter the former, which supplies the skin of the buttock, passes backwards through the sacro-tuberous ligament and round the lower border of the Gluteus Maximus; the latter passes forwards in front of the sacro-tuberous ligament, and is to be found on the Levator Ani between the tip of the coccyx and the anus, where it supplies the skin and gives twigs to the Sphincter Ani Externus.

The Anterior Coccygeal Plexus is formed by the anterior rami of S. 5 and C. 1 which emerge from the sacral hiatus on to the dorsum of the sacrum, because the lower ends of the sacrum and coccyx have, so to speak, been dissolved away (*fig. 633*). Therefore, to enter the pelvis these two rami require to bore through the structures attached to the side of the sacrum and coccyx (i.e., Gluteus Maximus, sacro-tuberous ligament, sacro-spinous ligament, and Coccygeus). This they do independently, one above, the other below the transverse process of the coccyx. In the pelvis they unite, and a descending twig from S. 4 joins them. The slender trunk so-formed descends, pierces the same structures again and appears on the back. This nerve corresponds to the *anterior caudal nerve* of tailed mammals. A similarly formed nerve, derived from the posterior rami of S. 4, 5, and C. 1, corresponds to the *posterior caudal nerve* of tailed mammals. In man these abbreviated anterior and posterior caudal nerves, together with other contributions from S. 4 (via its perineal branch, and the inferior haemorrhoidal nerve) supply a circular area of skin around the coccyx—the area on which one sits down (*fig. 528*).

THE FEMALE PELVIS

The female pelvis will be described under the following headings:

1. In median sagittal section.
2. Viewed from above.
3. The viscera:

a. The ovaries and the remnants of the gubernaculum ovarii.

b. The uterine tubes, uterus, and vagina—derived from Muller's ducts.

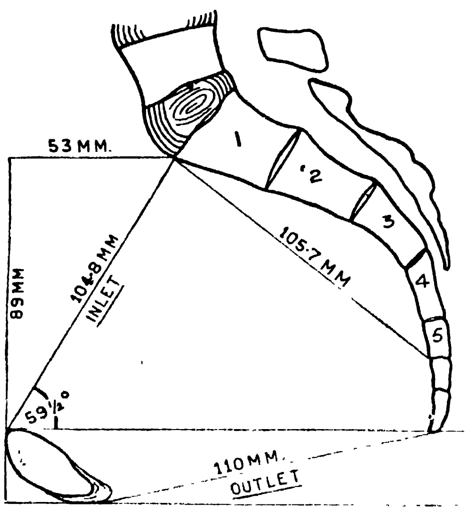


FIG. 354. Outlines of female pelvis in median section (drawn to scale).

c. The remnants of the mesonephric (Wolffian) tube and ducts

d. The ureter.

4. The vessels.

The Female Pelvis in Median Sagittal Section. You should be able to draw this to scale. First sketch the skeletal parts, then insert the viscera, and lastly put on the peritoneal covering. It is a good plan to use dividers or a graduated ruler.

1. The symphysis pubis with the inferior pubic ligament is $1\frac{1}{2}$ inches deep. Its posterior surface is flat and faces more upwards than backwards (*fig. 354*).

2. Erect a vertical line $3\frac{1}{2}$ inches high on the symphysis. Draw two parallel horizontal lines, one at the level of the top of the symphysis, the other at the top of the $3\frac{1}{2}$ inch line.

3. The sacral promontory lies on the upper horizontal line, three times the depth of the symphysis ($4\frac{1}{2}$ inches) from the upper end of the symphysis.

4. The tip of the coccyx lies on the lower horizontal line, three times the depth of the symphysis more or less ($4\frac{1}{2}$ inches) from the lower end of the symphysis.

5. The upper part of the sacrum is straight and parallel with the symphysis; its lower part and the coccyx are often much curved.

6. A line joining the upper end of the symphysis to the promontory of the sacrum is the plane of the pelvic brim or inlet of the pelvis. If you are interested in angles, note that it makes an angle of 60° with the horizontal, i.e., the equivalent to a third of two right angles. A line bisecting the pelvic inlet at right angles passes through the umbilicus.

7. A line joining the lower end of the symphysis to the tip of the coccyx is the plane of the outlet of the pelvis. It makes an angle of 15° with the horizontal A line bisecting it at right angles passes through the promontory.

8. Insert "the urogenital diaphragm and its upper and lower fasciae".

The soft parts are now to be inserted:

9. The bladder and urethra, as in the male: The urethra pierces the urogenital diaphragm an inch or less from the symphysis. It is an inch or more long (*fig. 355*).

10. The rectum and anal canal, as in the male: The rectum curves downwards and forwards from the third piece of the sacrum to a point $1\frac{1}{2}$ inches beyond (not below) the coccyx. There it makes a right-angled bend and thereafter, as the anal canal, passes downwards and backwards for an inch or more.

The uterus and vagina occupy in the female the positions taken by the seminal vesicles, ampullae of the vasa deferentia, and prostate in the male.

11. The vagina is about 4 inches long. It lies nearly parallel to the pelvic brim. Its anterior wall is in structural continuity with the urethra in its lower third ($1\frac{1}{4}''$); it is in contact with the bladder in its middle third ($1\frac{1}{2}''$); and it is pierced by the cervix of the uterus in its upper third ($1''$). Its orifice penetrates the urogenital diaphragm.

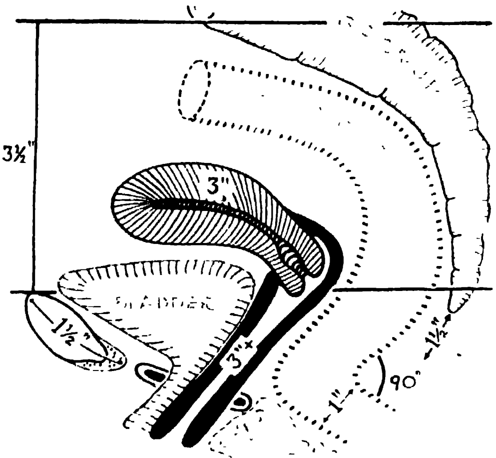


FIG. 355. The soft parts inserted in figure 354 (to scale).

12. The posterior wall of the vagina is separated from the rectum by the rectal and recto-vaginal layers of fascia; and from the anal canal by the triangular mass of fibro-fatty tissue called the perineal body (the perineum of the gynecologist).

13. The uterus is 3 inches long. It lies nearly at right-angles to the pelvic brim and to the vagina. Its upper 2 inches (or fundus and body) are one inch thick; its lower one inch or cervix is less than an inch thick. The external orifice of the uterus lies on (or below) the lower of the two parallel horizontal lines. The fundus does not reach to the pelvic brim. The body and cervix meet at a slight angle, so the uterus is said to be anteflexed.

14. The anterior and posterior fornices (fornix L. = an arch) of the vagina are the shallow depression in front of the anterior lip of the cervix and the deeper depression behind the posterior lip. The depression runs like a gutter all round the cervix; so, there are also a right and a left lateral fornix, but they are not seen in sagittal section.

15. The peritoneum passes from the symphysis on to the upper surface of the bladder, and from the third piece of sacrum on to rectum, as in the male. It falls an inch short of the anterior fornix of the vagina and, therefore, leaves the cervix uncovered in front, but it clothes half an inch or more of the posterior fornix (*fig. 356*). The peritoneum, therefore, caps the posterior fornix of the vagina in the female much as it caps the seminal vesicles in the male (*fig. 319.*)

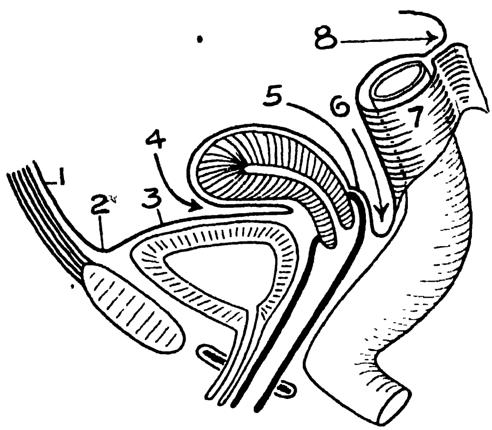


FIG. 356. The peritoneum of the female pelvis in median section (see text and *fig. 319*).

The Female Pelvis Inspected from Above. The bladder and the paravesical fossae are seen in front; the rectum and the pararectal fossae are seen behind, as in the male. It is the genital organs

that differ in the two sexes: (a) the uterus and vagina situated medianly replace the seminal vesicles, ampullae of the vasa deferentia, and prostate of the male; (b) the ovaries and their ducts (the uterine tubes), which are pelvic, replace the testes, which are scrotal, and their ducts (the vasa deferentia) which are in part pelvic (*fig. 357*).

The homologue of the recto-vesical pouch of peritoneum in the male is divided into an anterior and a posterior part by a transverse partition, formed by the uterus and the two folds of peritoneum, called the *broad ligaments of the uterus*, that pass from the lateral margins of the uterus to the side walls of the pelvis. The anterior subdivision is the *utero-vesical pouch;* the posterior is the *recto-uterine pouch* of Douglas. The uterus rests on the empty bladder and the shallow utero-vesical pouch is empty; the deeper recto-uterine pouch is occupied by pelvic colon and ileum.

The ovary is attached to the back of the broad ligament of the uterus by a short "mesentery", the *mesovarium.* The uterine tube occupies the upper border of the broad ligament except at its lateral end. The lateral end is continued as a fold, the *infundibulo-pelvic ligament,* across the external iliac vessels. A cord of fibro-muscular tissue passes backwards and upwards from the junction of the body and cervix of the uterus, past the rectum, to the sacrum. It helps to

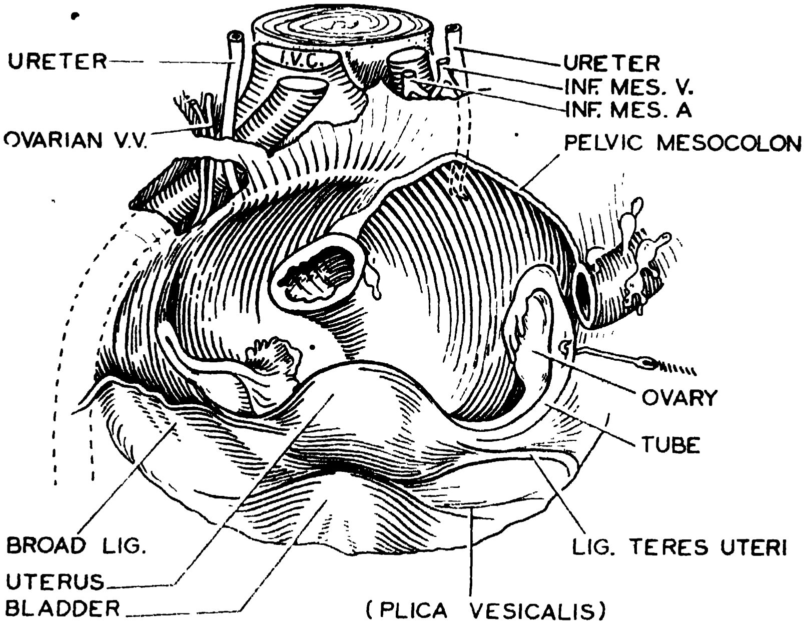


FIG. 35 Female pelvis (from above).

suspend the uterus and is called the *utero-sacral ligament.* The overlying crescentic fold of peritoneum is the *recto-uterine fold.*

A round fibro-muscular cord, the *ligament of the ovary* (ovario-uterine ligament), stands out in relief from the back of the broad ligament. It joins the lower pole of the ovary to the angle between the side of the uterus and the uterine tube. A similar cord, the *round ligament of the uterus* (lig. teres uteri), stands out from

the front of the broad ligament. It passes from the angle between uterus and tube across the pelvic brim to the deep inguinal ring (*fig. 358*).

The Female Internal Genital Organs comprise the ovaries, the uterine tubes, the uterus, and the vagina.

The Ovary is about the size and shape of an almond and its shell. It is covered with cubical epithelium—not peritoneum. The pits and scars on its surface mark the sites of the absorbed corpora lutea which result monthly between the 15th and 45th years from the shedding of ova. The mesovarium attaches its anterior border to the back of the broad ligament. The most lateral part of the free edge of the broad ligament, called the *infundibulo-pelvic lig.*, does not contain uterine tube; but it suspends the upper pole of the ovary from the external iliac artery and conducts the ovarian artery, vein, lymph vessels, and nerves to the ovary. Hence it is alternatively known as the *suspensory ligament of the ovary*. The lower pole of the ovary is attached to the lateral margin of the uterus by the ligament of the ovary.

The typical position of the ovary is on the side wall of the pelvis, behind the broad ligament, and in the fork of the internal and external iliac vessels—or more precisely, in the angle between the external iliac vein and the ureter. It is covered by the uterine tube which falls over it medially. But its position is variable.

The Gubernaculum Ovarii. How comes the ovary to enter the pelvis? Just as in the male the gubernaculum testis passed through the inguinal canal into the scrotum followed by the processus vaginalis and the testis, so in the female the *gubernaculum ovarii* passed through the inguinal canal into the labium majus followed by a *processus vaginalis peritonei* (the canal of Nuck). But, the gubernaculum ovarii acquired a side attachment to the uterus. As a result the ovary passed into the pelvis and drew its vessels and nerves across the external iliac vessels after it.

The gubernaculum in the female becomes the ligament of the ovary and the round ligament of the uterus; and these two ligaments are all but continuous at their sites of attachment to the side of the uterus just below the uterine tube. The round ligament in the female practically repeats the course taken by the vas

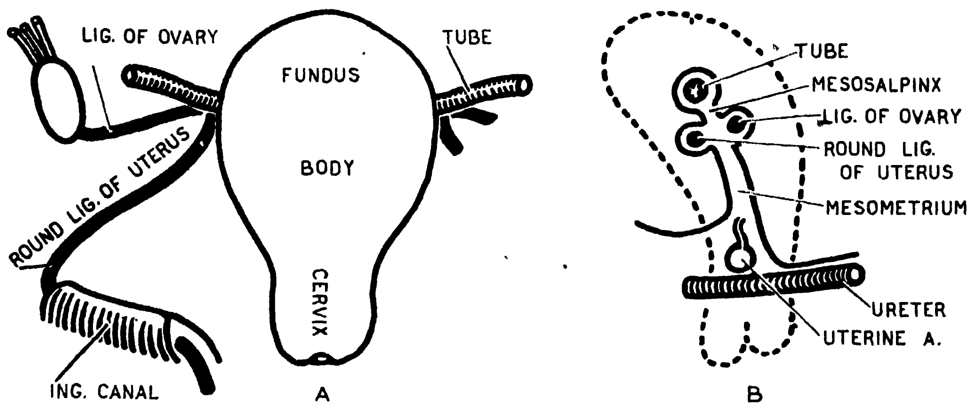


FIG. 358. (A) Derivatives of the gubernaculum ovarii—lig. of the ovary (lig. ovarii) and round lig. of the uterus (lig. teres uteri). (B) Sagittal section through broad ligament of uterus.

deferens in the male, i.e., it is subperitoneal; it crosses the side wall of the pelvis and the external iliac vessels; and it turns round the inferior epigastric artery, passes through the inguinal canal, and ends in the labium majus, which is the homologue of the scrotum.

At times the ovary does follow the gubernaculum into the labium majus It is then said to be ectopic.

The Derivatives of the Duct of Muller. Before the sex of the embryo is apparent two parallel, bilaterally symmetrical, mesodermal tubes grow caudally in the subperitoneal tissue of the posterior abdominal wall. In the urorectal septum all four tubes lie together and their terminal ends, which at this stage are blind, bulge into the caudal part of the anterior subdivision of the cloaca, called the *urogenital sinus*. The 4 tubes are named: the right and left Wolffian or mesonephric ducts and the right and left Mullerian or para-mesonephric ducts. The Wolffian ducts predominate in the male: they serve as sperm ducts and on each side become the duct of the epididymis, vas deferens, and ejaculatory duct. The Mullerian ducts predominate in the female: they serve as ducts for ova and become the uterine tubes, uterus, and vagina (*fig. 49, p. 64*). In the male the cranial end of each Mullerian duct persists as the appendix of the testis; the intermediate part disappears; the caudal end fuses with its fellow to form the prostatic utricle. The remnants of the Wolffian duct which persist in the female will be described later.

At the moment our interest is in the paramesonephric ducts of Muller in the female. Their cranial parts become the uterine tubes; their intermediate parts fuse to form the uterus; and their caudal ends fuse to form the upper part of the vagina, which at this stage is not canalized. As growth proceeds a solid plate of cells, the *vaginal plate*, extends downwards between the urogenital sinus and the rectum. Eventually this plate becomes canalized and joined by a right and a left upwardly growing diverticulum of the sinus to form the lower part of the vagina. The intermediate part of Muller's duct has to pull away from the side wall of the pelvis in order to meet its fellow in the median plane to form the uterus. The peritoneal fold thus-formed is called the broad ligament of the uterus; it is to be regarded as "the mesentery of Muller's duct" (*figs. 359, 49*).

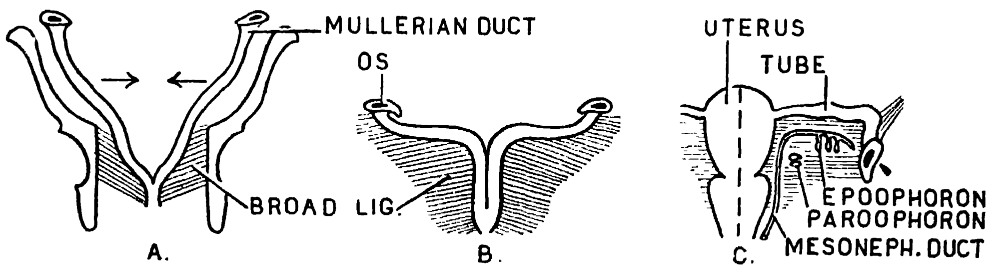


FIG. 359 The development of the broad ligament of the uterus or "mesentery of the Mullerian duct".

The Uterine Tube of Fallopius. The uterus is 2″ across at its widest part, which is where the tubes enter it. Each tube is about 4½″ long. The spread, therefore, of the uterus and its two tubes

is 11 inches. This is twice the diameter of the pelvic inlet ($5\frac{1}{2}''$). Evidently the tubes cannot lie in a straight line. Each tube occupies the free edge of the broad ligament, which is its mesentery, and runs from the uterus upwards, laterally, and backwards to the side wall of the pelvis and there curves backwards over the ovary (*fig. 360*).

Each tube has the following parts: *infundibulum, abdominal orifice, ampulla, isthmus, uterine part,* and *uterine orifice.* The *abdominal orifice* 2-3 mm. in diameter, lies at the bottom of a funnel-shaped depression, the *infundibulum.* Fringes or fimbriae lined with ciliated epithelium, project from the infundibulum and encourage ova, when shed, into the tube. One fimbria is attached to the ovary. The main part of the tube is long, irregular, and dilated, and is called the *ampulla.* The succeeding shorter part is straight and narrow and is called the *isthmus.* The *uterine part* passes through the uterine wall, which is half-an-inch thick. Four longitudinal folds, bearing secondary folds, project into the lumen of the tube, which is lined with columnar ciliated epithelium.

The Uterus is the thick-walled muscular receptacle in which the fertilized ovum develops through embryonic and foetal stages into a child. It is pear-shaped, 3 inches long, 2 inches at its widest part, and 1 inch or less at its thickest part. It is flattened in front where it rests on the bladder; and it is convex behind. The uterine or Fallopian tubes enter it at its widest part. The broad ligaments are attached to its margins; the ligament of the ovary and the round ligament of the uterus are attached just below the tube. It is divided into three parts—a *fundus,* a *body,* and a *cervix.* The fundus and body form the upper two inches; the cervix the lower one inch. The fundus is the part that rises above the tubes. The uterine artery runs tortuously up the side of the uterus between the layers of the broad ligament. The *external os* of the uterus is round in the virgin. It becomes a transverse slit guarded by an anterior and a posterior lip in those who have borne children. There is a slight angle at the junction of the body and cervix, so the uterus is said to be anteflexed. The uterus seldom lies in the median plane, but is deflected to one side or other. The potential *cavity of the body* of the uterus is triangular; the

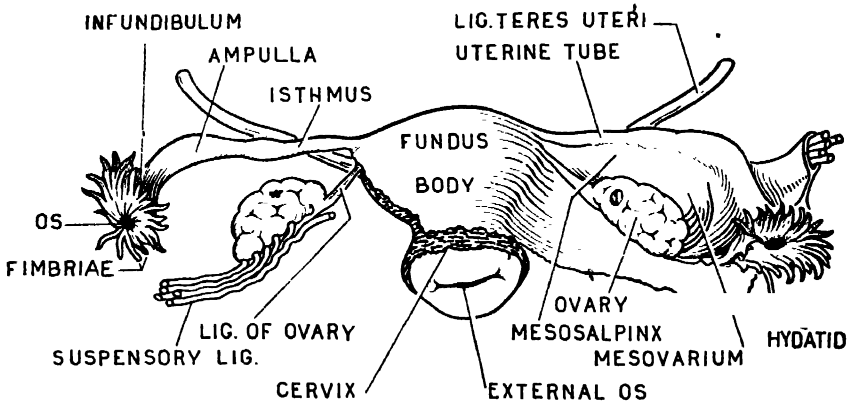


FIG. 360. The uterus and appendages (from behind).

uterine orifices of the tubes, which are about 1 mm. in diameter, open at the upper lateral angles, the *internal os of the uterus* at the lower angle. The anterior and posterior walls are applied to each other. The *cervical canal* (cavity of the cervix) extends from the internal os to the external os of the uterus. It is spindle-shaped and one inch long.

the muscle coat except at the sides, where it passes on to the broad ligaments. The mucous coat (endometrium) is thick and is lined with columnar cells, many of which are ciliated, and it possesses numerous tubular glands which extend to, or even into, the muscle coat.

In the cervix the muscle bundles are largely circularly arranged, as at a sphinc-

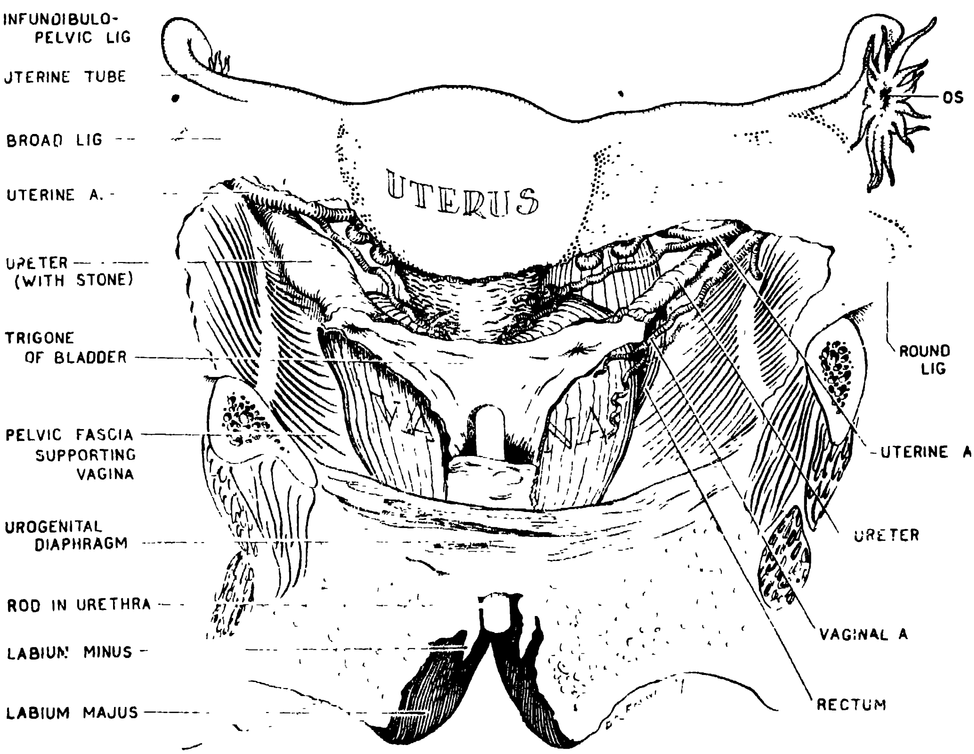


FIG. 361. The female internal genitalia. For legend see fig. 362.

STRUCTURE: The uterus has three coats —serous, muscular, and mucous. *In the fundus and body* the muscle coat (myometrium) is nearly ½″ thick and consists of interlacing bundles of involuntary muscle, an arrangement which, at the end of pregnancy, brings about the natural arrest of haemorrhage by constricting the penetrating vessels. The serous (peritoneal) coat is adherent to

ter. The mucous membrane is thrown into branching folds, is lined with columnar mucous secreting cells, and possesses both simple and branched tubular mucous secreting glands.

The Vagina (L. = a sheath or scabbard) is about 4 inches long and is approximately parallel with the pelvic brim. It extends from the vulva through the urogenital diaphragm to the recto-uter-

ine pouch of Douglas. Its anterior and posterior walls are applied to each other. Its anterior wall is structurally continuous with the urethra in its lower third; in contact with the bladder in its intermediate third; and is pierced by the cervix in its upper third. Around the cervix there is a circular gutter, described as the anterior, posterior, and lateral *fornices of the vagina.* As the anterior aspect of the cervix is not covered with peritoneum, the anterior fornix is an inch from the utero-vesical pouch of peritoneum; but the posterior fornix is clothed with peritoneum of the recto-uterine pouch of Douglas—and, note that an instrument, forced upwards through the posterior fornix of the vagina, would enter this peritoneal pouch.

Each lateral fornix is crossed by the base of the broad ligament, the uterine artery, and the ureter. Because the uterus is seldom median in position, the ureter is less than half-an-inch from the cervix on one side (generally the left) and more than half-an-inch on the other (*fig. 362*). The posterior wall of the vagina is separated from the rectum by the recto-vaginal and rectal layers of pelvic fascia, and from the anal canal by the perineal body. The pouch of Douglas is 3" from the anus. The side walls of the vagina are supported by the Levatores Ani; its lower part passes (a) between the anterior borders of the Levatores Ani; (b) through the urogenital diaphragm and its fasciae; (c) between the bulbs of the vestibule and the Bulbospongiosus, and (d) it is guarded by the labia minora and majora. (*Fig. 317.*)

STRUCTURE: Like the mouth, the lower part of the pharynx, and the esophagus, the vagina is lined with stratified squamous epithelium. This covers a *tunica propria* which presents numerous transverse folds (rugae) and papillae, and contains numerous lymphocytes. Outside this there is a thin *muscle coat* of longitudinal fibres and some interlacing circular ones, and a thick fibro-areolar *adventitious coat.* Though the vagina possesses no glands, the epithelial surface is moist, since it receives the secretion from the cervical canal. The stratified squamous epithelium is reflected from the vagina on to the cervix and clothes it as far as the external os.

Remnants of the (Wolffian) Mesonephric Duct and Body (*figs. 49, 50, 359*) persist in the female as the *epoophoron, paroophoron,* and *duct of Gartner.* Because they commonly become cystic and cause trouble they are of clinical importance. Naturally, they are to be sought for at the sides of the (Mullerian) paramesonephric ducts, now converted into the uterine tubes, uterus, and vagina. *The epoophoron* (= above the egg basket) lies between the layers of the broad ligament, above the ovary. It is a vestigial part of the mesonephric duct and mesonephric tubules; it corresponds to the duct of the epididymis and efferent ducts of the testis of the male. *The paroophoron* (= beside the egg basket) lies between the layers of the broad ligament, medial to the ovary. It is formed from mesonephric tubules and corresponds to the aberrant ducts of the epididymis in the male. *The duct of Gartner* is a segment of the mesonephric duct which lies in front of the anterior wall of the vagina. It corresponds to the end part of the vas deferens in the male. (*Figs. 49, 50, 359.*)

It may be mentioned here that *paraurethral glands*, corresponding to prostatic glands, open on to the skin surface on each side of the urethral orifice.

The Ureter descends on the side wall of the pelvis, as in the male, crossing in turn the external iliac vessels, the Psoas,

the pelvic brim, the obturator nerve, artery and vein, the obliterated umbilical artery, and the Levator Ani. It lies in front of the internal iliac artery, and it is crossed by the uterine artery. In the male it is crossed by the Wolffian duct or duct of the testis; so in the female it is crossed by the Mullerian duct or duct of are in front of the anterior fornix as they pierce the postero-lateral angles of the bladder two inches apart.

The Arteries Peculiar to the Female Pelvis — ovarian, uterine, and vaginal.

The Ovarian Artery arises from the aorta, like the testicular a., but differs from it in crossing the external iliac ves-

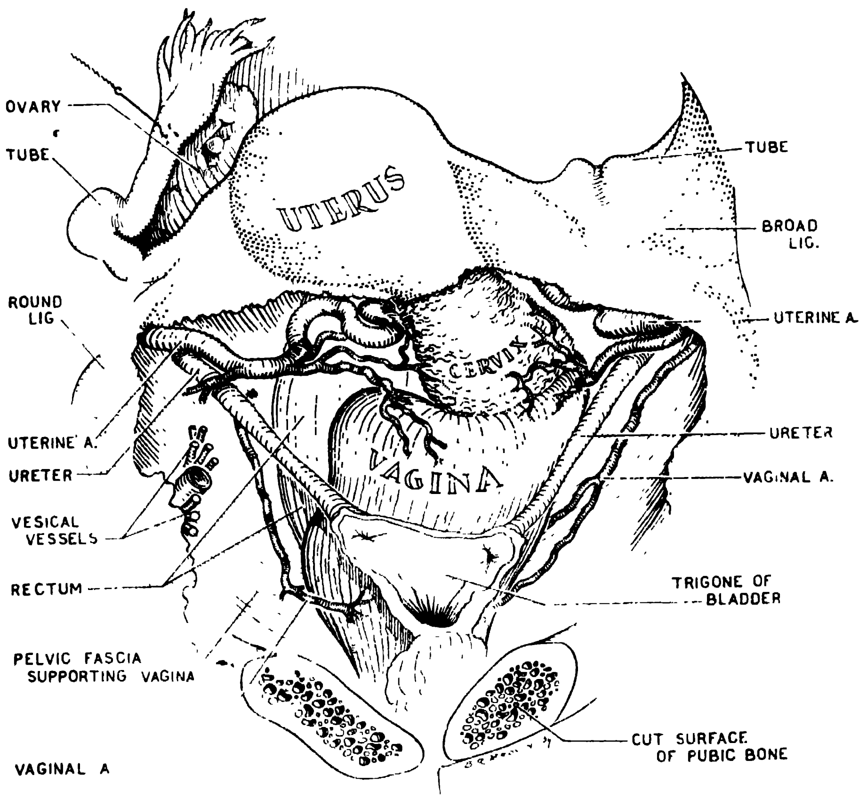


FIG. 362. The female internal genitalia. (Parts of the pubic bones and all of the bladder, except the trigone, have been removed.) 361. Uterus symmetrically placed (note stone in ureter). 362. Uterus deflected. Note the variable relations of the ureters to the lateral fornices of the vagina and to the cervix. (Dissections by Dr. B. L. Guyatt.)

the ovary which lies in the free edge of the broad ligament (*fig. 283*).

The relations peculiar to the female are these: the ureter crosses the lateral fornix of the vagina below the broad ligament and uterine artery, where it lies closer to the cervix on one side (generally the left) than on the other. The ureters

sels, about half an inch in front of the ureter in the infundibulo-pelvic ligament (suspensory lig. of the ovary). It supplies the ovary and part of the tube, and anastomoses freely with the uterine a. The ovarian a. is commonly so slender that its duties are largely assumed by the uterine artery.

The uterine and vaginal arteries are the equivalents of enlarged inferior vesical arteries in the male (*fig. 363*).

The Uterine Artery is a large vessel. It arises from the anterior division of the internal iliac a. It descends in front of the ureter to the base of the broad ligament and, at the lateral fornix of the vagina, it crosses above the ureter. After sending branches to the vagina and cervix, it continues tortuously up the side of the uterus between the layers of the broad ligament. It ends by anastomosing with the ovarian artery. It sends a branch to the round ligament.

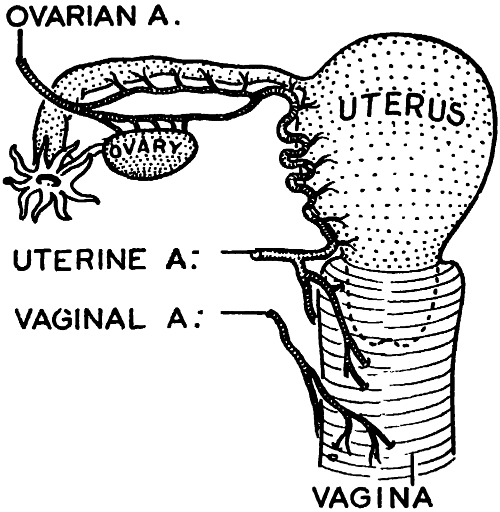


FIG. 363. The uterine vessels.

The Vaginal Artery descends to the vagina, sends branches to its anterior and posterior surfaces and supplies twigs to the bladder.

VEINS. *The Ovarian Vein* arises from the ovary as the pampiniform plexus. The plexus surrounds the ovarian artery, crosses the pelvic brim as a single vein, or as several veins that soon unite, and opens into the i. v. cava or left renal vein according to the side.

The uterine and vaginal *plexuses of veins* join the vesical plexus and pass as several large branches to the internal iliac vein (p. 348).

The Support of the Female Pelvic Viscera. EXTERNALLY: As in the male, so in the female, the thick pubic parts of the Levatores Ani form a sling for the rectum, drawing it forwards until it forms a sloping shelf (*fig. 332*). Upon this shelf the vagina and bladder rest. The pubic parts of the Levatores Ani are also inserted into the perineal body and, therefore, act as a suspensory muscle for the lower parts both of the posterior wall of the vagina and of the anterior wall of the rectum; hence, rupture of this body leaves these two applied walls so poorly supported that they tend to slip downwards.

The urogenital diaphragm fixes the lower third of the vagina and assists the Levatores Ani to support it.

INTERNALLY: Two fan-shaped fibromuscular sheets, the right and left *cardinal ligaments*, are attached to the sides of the upper two-thirds of the vagina and supravaginal part of the cervix and form their chief support. These sheets blend with the fascia of the Levatores Ani and are attached with the Levatores Ani to the side wall of the pelvis. The posterior borders of the cardinal ligaments (uterosacral ligs.) are free and concave and, like a sling, curve backwards and upwards from the junction of the body and cervix of the uterus towards the middle piece of the sacrum. The rectovesical fascia with its contained vessels passes medially from each side-wall of the pelvis and sends coverings to both surfaces of the vagina. The uterus is thrust forwards into the anteflexed position by coils of ileum occupying the recto-uterine pouch of peritoneum, and the broad ligaments steady it there so that it rests upon the bladder The utero-vesical

pouch is a potential space—normally unoccupied by gut.

Slips of involuntary muscle everywhere pervade the pelvic fascia and give it a supporting value not appreciated after death. This, no doubt, accounts for the remark of Victor Bonney—"The cardinal ligaments can only be properly studied in the living". Muscular bands pass from the inferior pubic ligament to the anterior wall of the vagina and cervix.

THE DIFFERENCES BETWEEN THE MALE AND FEMALE PELVIS

The female pelvis may be contrasted with the male pelvis under the following headings:

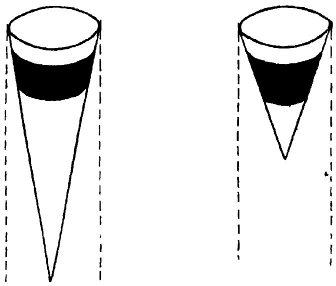


Fig. 364. The male and female true pelves (colored black) as segments of cones.

1. Features dependent on the fact that woman is the weaker vessel.

2. Features related to the peculiar function of the female true pelvis and affecting: (a) the cavity, (b) the transverse diameter, and (c) the antero-posterior diameter.

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1. Features Dependent on the Fact that Woman Is the Weaker Vessel.

Women are less muscular than men; they are five inches less one lar than men; other in stature; and they weigh less. For these and other reasons their bones, including the bones of the pelvis, are lighter and the ridges and markings for tendons, aponeuroses, and fasciae are less pronounced.

Joints. The articular surfaces of all joints associated with the pelvis are relatively and absolutely smaller in the female. In order of significance these joints are: (1) the lumbo-sacral joint, (2) the hip joint, (3) the symphysis pubis, and (4) the sacro-iliac joint. The oval articular facet on the base of the sacrum and the acetabulum are both strikingly small. [As a result of "rheumatic" conditions there may be a broad

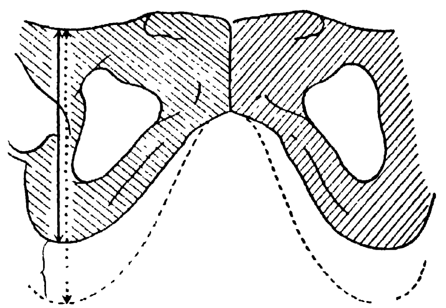


Fig. 365. The pelvic cavity is shallower in the female and the subpubic angle is greater.

rim around the oval facet on the sacrum. This is not to be confused with the outline of the articular surface.] The symphysis pubis is short. The sacro-iliac facet crosses the 1st and 2nd sacral vertebrae and encroaches on the 3rd vertebra; in the male it extends nearly half way down the side of the 3rd vertebra (*fig. 327*).

2. Features Related to the Peculiar Function of the Female True Pelvis (Pelvis Minor). During parturition the true pelvis becomes a passage for the child. The length of the passage and its diameters are modified in accordance with requirements, as follows:

A. The Cavity: The male true pelvis has been described very aptly as a long segment of a short cone; the female, as a short segment of a long cone (*figs. 364, 365*), i.e., in the male it is deep and funnel-shaped; in the female it is shallow and tubular.

Diameters. The three diameters of the pelvic brim or inlet are: the *antero-posterior diameter* (internal conjugate) measured from the sacral promontory to the top of the symphysis pubis; the *oblique diameter* measured from the sacro-iliac joint to the ilio-pubic eminence of the opposite side (prior to the age of 16 this is the ilio-pubic synchondrosis), and, the *transverse diameter* measured at the widest part of the brim, which is behind the centre. The diameters of the outlet are: the *antero-posterior diameter,* measured from the lower end of the symphysis to the tip of the coccyx. Its length depends largely upon the mobility of the sacro-coccygeal joint; so, it is very variable. The *transverse diameter* is taken behind the ischial tuberosities.

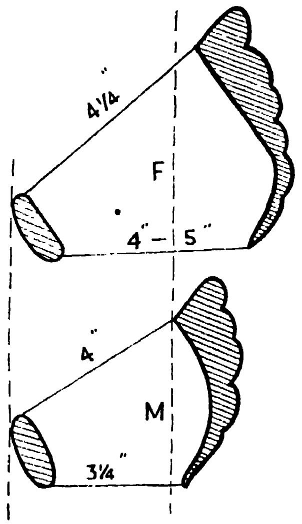


Fig. 366. Pelvic cavities on median section: male and female compared.

All diameters are absolutely greater in the female than in the male (*fig. 367*), each of the three diameters of the inlet being about ½" greater; and the antero-posterior and transverse diameters of the outlet being about 1" greater.

B. The Transverse Diameter or Breadth is greater in the female than in the male. This reveals itself to inspection thus: (1) The body and the crest of the pubic bone are wider in the female than in the male; so, the pubic tubercles are farther apart. (2) The acetabulum is approximately its own diameter distant from the symphysis in the male, but in the female it is about an inch more than its own diameter distant from the symphysis. The fact that the female acetabulum is also relatively small accentuates this characteristic.

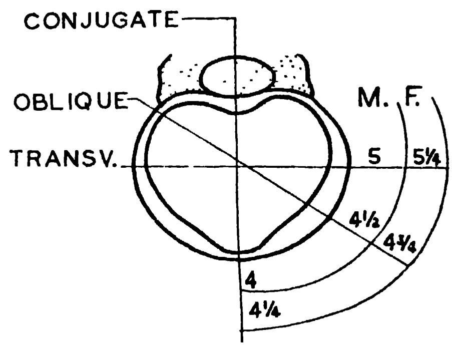


Fig. 367. Diameters of pelvic brim: male and female compared.

(3) The base of the female sacrum is relatively wide, and, the oval facet on the base is relatively very small; so, for a two-fold reason the alae are relatively long. In the male the oval facet is nearly half (43.5 per cent) the maximum width of the base of the sacrum and is therefore much greater than either ala; in the female the oval facet is little more than a third (38.5 per cent) of the width of the base and is therefore approximately equal to the width of an ala (*fig. 368*). (4) The female pubic arch is almost a right angle; it equals the angle between the out-stretched thumb and the index finger. In the male it is an acute angle,

equal to the angle between the index and middle fingers when spread. (5) The female ischial tuberosities are everted.

C. THE ANTERO-POSTERIOR DIAMETER is greater in the female than in the male. This is revealed to inspection thus: (1)

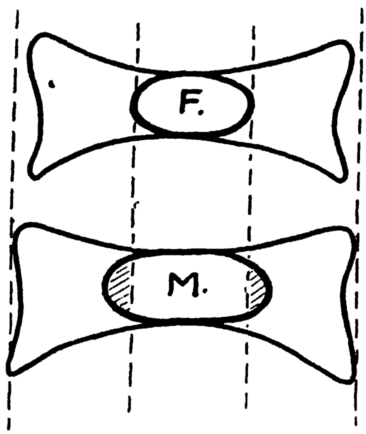


FIG. 368. Base of sacrum: male and female compared.

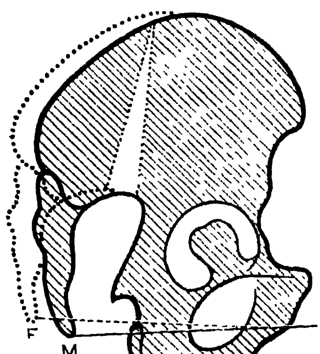


FIG. 369. Conversion of the male outlet into the female enlarges the angle of the greater sciatic notch.

At the inlet the promontory is carried backwards in the female. Consequently, the female inlet tends to be round; the male to be heart-shaped. (2) *At the outlet* the coccyx is carried backwards in the female, (a) by raising the hinder part of the iliac crest, and thereby (b) increasing the angle of the greater sciatic notch, which in the male is an acute angle, to approximately a right angle in the female. The addition to the male pelvis of a wedge of bone, whose base is at the greater sciatic notch and apex at the iliac crest, would achieve these three effects (*fig. 369*).

3. The Attachments of the External Organs of Generation. In the male the pubic arch has an expansive flat area for the attachment of the crus penis; so, it is thick and it appears to be everted. In the female the area for the crus clitoridis, naturally, is narrow and the arch is thin.

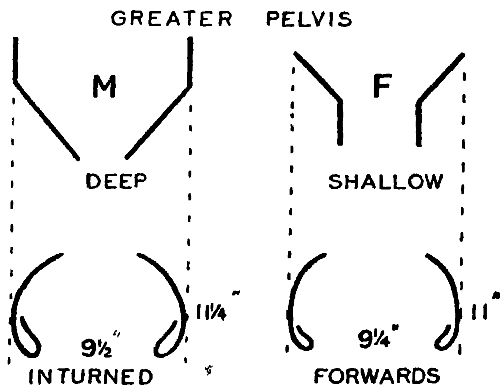


FIG. 370. Iliac crests: male and female compared.

4. Features of the False or Greater Pelvis and Other Features. In the male the walls of the false pelvis are steep and the anterior superior iliac spines inturned. In the female the false pelvis is shallow and the anterior superior spines rather point forwards (*fig. 370*). The interspinous diameter (i.e., between anterior superior iliac spines) and the intercristal diameter (i.e., between the widest parts of the iliac crests) is each slightly less (10 mm.) in the female than in the male. Skirting the anterior margin of the auricular facet on the ilium there may be a deep groove, the *pre-auricular sulcus*

(Derry). A shallow groove may occur in the male, but a broad deep groove is peculiar to the female. The cause of the groove is not obvious.

Identification. In cases where it is difficult to arrive at a decision as to the sex of a given pelvis, greatest weight should be placed upon: (1) the area for the attachment of the crus penis or clitoridis; (2) the angle of the pubic arch; (3) the size of the acetabulum; (4) the size of the facet on the base of the sacrum relative to the alae; (5) the distance of the acetabulum from the symphysis pubis.

Male and female pelves are distinguishable from each other by the fourth fetal month, but it is not until puberty that sexual differences become marked. It is, however, not possible to tell the sex of all pelves.

Types of Female Pelvis. Female pelves by no means all conform to the description given above; and since for the obstetrician it is of practical importance to know the dimensions and shapes of the pelves of his patients, various classifications have been proposed.

Thoms has classified the pelves of 300 primiparous white women (delivered consecutively at a hospital clinic) into four major groups according to the dimensions of the pelvic inlet as determined by X-ray.

Percentage Incidence of Pelvic Types
(After Greulich and Thoms)

TYPE	300 CLINIC QATIENTS	100 NURSES	107 GIRLS AGE 5–15
Dolichopellic	16.3	37	57.9
Mesatipellic	44.0	46	33.6
Brachypellic	36.3	17	8.3
Platypellic	3.3	—	—

Dolichopellic (long): a-p. diameter > transverse diameter.
Mesatipellic (round): transverse > a-p. diameter by 0–1.0 cm.
Brachypellic (oval): transverse > a-p. diameter by 1.1–2.9 cm.
Platypellic (flat): transverse > a-p. diameter by 3 cm. or more.

When the pelves of 100 nurses, who were superior physically and more fortunate economically, are compared with those of the 300 women, a shift towards the dolichopellic type is seen. When the pelves of 107 girls, aged 5–15 years, from an orphanage are in turn compared, a further shift is seen. Indeed, before the age of 12 years over 75 per cent of these pelves were dolichopellic.

The size and shape of the pelvis are influenced by various factors (hormonal, environmental, hereditary, and mechanical), but it is not until puberty that the predominantly dolichopellic pelvis of childhood changes to one of the adult types. This remoulding takes about 18 months after which there is very little growth and almost no change in the shape of the inlet. Greulich and Thoms.)

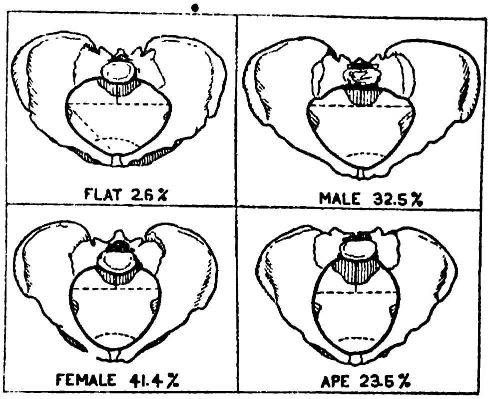


FIG. 371. The inlets of the 4 major types of female pelvis. (After Caldwell and Moloy.)

Caldwell and Moloy with Todd's skeletal material as a basis, also have divided the white female pelvis into four major groups: (a) anthropoid (ape), (b) android (male), (c) gynecoid (female) and (d) platypelloid (flat). Figure 371 illustrates the characteristics of the pelvic inlet in these four different groups and

their percentage incidence. It shows the position of the greatest transverse diameter, and draws attention to the differences in the anterior and posterior segments of the inlet, to the size of the angle (retropubic angle) of the anterior segment, and to the lengths of the pubo-iliac and iliac portions.

Todd made measurements of part of this material when it was approximately fresh and unmacerated, so his mean measurements given in the accompanying table are of particular interest.

Average Antero-posterior (Conjugate) and Transverse Diameters of the Pelvic Inlet in White Females, Classified, according to the Four Pelvic Types of Caldwell and Moloy.
(After T. W. Todd)

PELVIC TYPE	NUMBER OF CASES	CONJUGATE DIAMETER IN CM.	TRANSVERSE DIAMETER IN CM.
Gynecoid	26	10 86	13.76
Android	25	10.59	13.56
Anthropoid	19	11.75	12.94
Platypelloid	3	8.55	14.45
Mixed Average for Females	73	10.90	13 51
Average for Males	43	10 10	13.00

THE AUTONOMIC NERVES WITHIN THE PELVIS

The autonomic nerves within the pelvis are:

(1) the sympathetic trunks,
(2) the hypogastric plexus, and
(3) the pelvic splanchnic nerves.

The Sympathetic Trunk, you will recall (p. 293), enters the abdomen behind the medial arcuate ligament and follows the origin of the Psoas. It, therefore, lies on the bodies of the vertebrae and is separated from them only by the horizontally running lumbar vessels. It passes behind the common iliac artery to reach the pelvis. The i. vena cava conceals the right sympathetic trunk.

Each trunk has four or more ganglia. A white ramus communicans passes from each of the upper 2 or 3 lumbar nerves to the trunk; and one or more grey rami communicantes pass from the trunk to each of the five lumbar nerves. The rami communicantes accompany the lumbar vessels laterally and backwards round the sides of the vertebral bodies. Branches (lumbar splanchnic nerves) pass from the trunk (or ganglia) medially to the pre-aortic (intermesenteric) plexus, which is a downward extension of the celiac plexus (*fig. 767*).

The trunks of the two sides end in front of the coccyx in a medianly placed ganglion of no importance, the *coccygeal ganglion* (ganglion impar). The two trunks, therefore, converge as they descend on the bodies of the sacrum—i.e., they lie medial to the anterior sacral foramina (*figs. 301, 353*). They send grey rami laterally to each of the sacral nerves and to the coccygeal nerve; and a few twigs pass medially to join the pelvic plexus.

The Hypogastric Plexus or Presacral Nerve lies below the bifurcation of the aorta and in front of the left common iliac vein and promontory of the sacrum. It is a downward prolongation of the pre-aortic (intermesenteric) plexus, reinforced by the lumbar splanchnic nerves.

On each side a combined 1st and 2nd lumbar splanchnic joins it after crossing in front of the common iliac artery and separate 3rd and 4th lumbar splanchnics join it after crossing behind the artery (and vein). Its preganglionic cell stations are in the lowest thoracic and upper lumbar segments of the spinal cord. From one to four branches enter the pelvis and descend in front of the sacrum as *right and left pelvic plexuses.* They are joined by twigs from the upper sacral sympathetic ganglia and by the pelvic splanchnic nerves.

The Pelvic Splanchnic Nerves (nervi erigentes) are most easily found by passing two fingers downwards in front of the body of the sacrum, easing the rectum forwards, and feeling in the sheet of areolar fascia that runs forwards on each side to the rectum. They spring from sacral nerves 2, 3, and 4. On the side of the rectum they join the corresponding pelvic plexus, which then becomes mixed sympathetic and para-

and bulb of the penis. Others pass below the symphysis pubis with the deep dorsal vein of the penis, join the dorsal nerve of the penis, and are distributed to the cavernous and spongy tissue of the penis.

Formerly, it was taught that the pelvic splanchnic nerves and the branches of the hypogastric plexus are antagonistic—or complementary—to each other, in that they maintain a balance, both supplying

TABLE 16

Structures Crossing the Pelvic Brim

In enumerating these you should follow some system, any system will do, and the following suggested:

Structures: Pertaining to the G-I Tract	Coils of ileum. Pelvic colon mesocolon. Inferior mesenteric a., v., lymph vessels and nerves. Hypogastric plexus (to pelvic viscera generally).
Pertaining to the U-G Tract	Ureter. Vas deferens. Bladder when it fills.
Pertaining to the body wall (somatic structures)	Muscles: No muscles cross the brim and obstruct the p. inlet. Therefore, fascia reaching the brim is attached to it. Nerves: lumbo-sacral trunk. obturator nerve. Sympathetic trunk. Vessels: median sacral a. and v. Ilio-lumbar a. internal iliac a., v., and lymph vessels.
Peculiar to the female	Ovarian a, v, lymph vessels and nerves. Round ligament of uterus. Uterus when it fills.
Variable with age	Cecum tends to glide into pelvis in the aged. Bladder is abdominal in children.
Abnormal and variable	Abnormal obturator artery and vein. Appendix (commonly).
Of morphological interest	Urachus. Obliterated umbilical arteries.
Peculiar to race	?

sympathetic". The plexus forms a dense network applied to the medial side of the vessels that limit the retro-pubic space posteriorly. Mixed branches are distributed with these vessels to the various pelvic viscera, the pelvic splanchnics constituents being the more important. Branches continue forwards to the side of the bladder and prostate; and beyond the prostate, branches pierce the urogenital diaphragm and enter the crus

the involuntary muscles derived from the cloaca; that the pelvic splanchnics inhibit the internal sphincters of the bladder and anal canal and at the same time cause the bladder and rectum to contract and expel their contents; and that the hypogastrics have the contrary effect; they cause contraction of the sphincters and relaxation of the walls of the bladder and rectum.

It is now generally believed that the

sympathetic has no influence on the muscle wall of the bladder or urethra—except as stated on page 63. The parasympathetic has exclusive control. (Sheehan.)

The pelvic splanchnics send ascending fibers across the left common iliac artery to join the sympathetic plexus on the inferior mesenteric artery and are distributed with it to the descending and pelvic colons (Stopford).

The pelvic splanchnics by causing relaxation of the arteries to the cavernous tissue, which normally are in contraction, produce erection of the penis (or clitoris) —hence the original term—nervus erigens.

The hypogastrics, when stimulated, cause the epididymis, vas deferens, seminal vesicles, and prostate to contract and empty their contents; at the same time the region of the neck of the bladder is shut off (Learmonth). Hence, on ejaculation, the seminal fluid is hindered from entering the bladder.

Structures Crossing the Pelvic Brim. You will find it a profitable exercise to make a list of the structures crossing the brim. Although they and their positions are now known to you, it is more than likely that the list you compile will have important omissions, unless your approach is systematic. Thus, you may name the structures encountered from front to back, or from back to front; or you may consider first the vessels, next the nerves, and then the viscera; or you may group them, as in table 16, under the headings gastro-intestinal tract, urogenital tract, body wall, etc., which is the routine method adopted in this book.

PELVIC LYMPHATICS

The Inguinal Glands. There is a superficial and a deep group of inguinal glands. (1) *The superficial inguinal glands* are themselves arranged in two intercommunicating subgroups which are commonly palpable in thin, healthy persons: (a) the upper subgroup lies parallel to the inguinal ligament below the attachment of Scarpa's fascia to the fascia lata; (b) the lower subgroup is applied to both sides of the upper end of the long saphenous vein. (2) *The deep inguinal glands* lie medial to the upper end of the femoral vein, one (the gland of Cloquet) occupying the femoral canal.

Nearly two dozen lymph vessels leave the superficial and deep inguinal glands, pass behind the medial two-thirds of inguinal ligament, and end in the external iliac glands (*fig. 372*). These lymph vessels are arranged around the femoral artery and vein, some lying lateral to them, some in front of them, some behind them, and some medial to them; the medial ones numbering 9 or 10 pass through the femoral canal and may or may not be interrupted by the gland of Cloquet. (*See page 374.*)

The Pelvic Glands are in two groups: (1) those near the pelvic brim, and (2) those within the pelvic cavity. The glands near the brim (12 or more) are (a) the *external and common iliac glands*, which are arranged as several intercommunicating chains around the respective blood vessels, and (b) the glands above the *sacral promontory*. The glands within the cavity are the *internal iliac, lateral sacral,* and *median sacral glands* arranged on the respective blood vessels; and others in the *vesical fascia,* in the *rectal fascia* mainly behind the rectum (pararectal glands) and on the course of the superior rectal artery, ***in the broad ligament*** near the cervix uteri, and between the prostate and rectum.

Structures Drained. The structures

are drained chiefly by lymph vessels traveling to lymph glands as follows:

THE SKIN OF THE PENIS AND THE PREPUCE → with the superficial dorsal vein in the subcutaneous tissues to the superficial inguinal glands of both sides.

THE GLANS PENIS AND THE PENILE URETHRA → accompany the deep dorsal vein deep to the fascia penis to the supero-

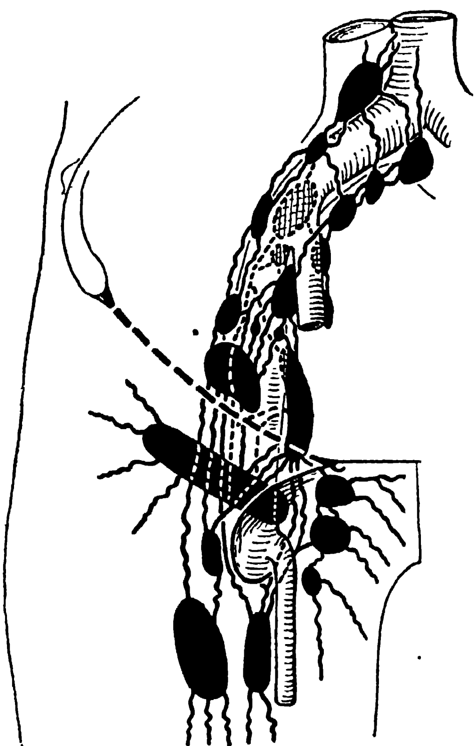


FIG. 372. Dissection of the inguinal and pelvic lymphatics.

medial group of inguinal glands of both sides, thence to the external iliac glands. Some vessels pass without interruption through the femoral and inguinal canals to the external iliac glands. The lymph vessels of the glans and of the prepuce anastomose.

BULBAR URETHRA → follows the pudendal artery to internal iliac glands, and the deep dorsal vein below the infrapubic ligament, thence to external iliac glands.

MEMBRANOUS AND PROSTATIC URETHRAE (OR WHOLE FEMALE URETHRA) → internal iliac glands.

BLADDER (superior and infero-lateral surfaces) → follow the general course of the branches of the superior vesical artery, vas deferens, and ureter to external iliac glands lying along the medial side of the external iliac vein, some being interrupted by anterior and lateral vesical glands.

BASE OF THE BLADDER AND THE MALE INTERNAL GENITAL ORGANS (prostate, seminal vesicles, ampullae of the vasa) → internal iliac glands; also to the external iliac glands; and on the Levator Ani to the sacral glands.

ANUS AND LOWEST PART OF THE ANAL CANAL → by cutaneous vessels to the superficial inguinal glands.

Anal canal → internal iliac glands by vessels crossing ischio-rectal fossa with branches of the pudendal vessels and by others following the middle rectal vessels.

RECTUM → (a) pararectal glands, thence to the superior rectal and inferior mesenteric glands; (b) lateral and median sacral glands and, (c) with the middle rectal artery to internal iliac glands.

OVARY, like the testis, → lateral aortic and pre-aortic glands, between the levels of the common iliac vessels below, and the renal vessels above. Owing to the absence of a left inferior vena cava they are more accessible on the left side, here however, the inferior mesenteric artery obtrudes itself. Occasionally a vessel passes to a gland at the bifurcation of the common iliac artery.

UTERINE TUBE AND FUNDUS OF THE UTERUS → with those of the ovary,

ending in the lower pre-aortic and lateral aortic glands. They traverse the broad ligament and cross the pelvic brim.

Body of Uterus → via broad ligament to the external and common iliac glands and by a single vessel running in the round ligament to the supero-medial group of superficial inguinal glands.

Cervix of Uterus and Upper End of Vagina → with uterine and vaginal arteries to internal iliac glands; also to external iliac glands, and passing close to the rectum to sacral glands.

Lower End of Vagina and labium majus, like the scrotum → to superficial inguinal glands.

SECTION V

THE LOWER LIMB

CHAPTER 14

INTRODUCTION

The human skeleton is naturally divided into two main parts:

1. The axial skeleton—skull, vertebral column, ribs, and sternum.
2. The appendicular skeleton—upper and lower limbs.

The homologous bones in the two limbs are:

	Upper Limb	*Lower Limb*	
Pectoral girdle	Scapula	Ilium	Pelvic girdle
	Coracoid process	Ischium	
	Clavicle	(Pubis)	
	Humerus	Femur	
	Radius and Ulna	Tibia and Fibula	
	Carpal bones	Tarsal bones	
	Metacarpal bones	Metatarsal bones	
	Phalanges	Phalanges	

Rotation of the Limbs. During intrauterine life the thumb and radius, and the big toe and tibia lie on the cephalic borders of the respective upper and lower limbs. The palms of the hands and the soles of the feet are so placed that the fetus could almost clap its hands and clap its feet. The limbs rotate on their own long axes, but in opposite directions, i.e., the thumb and radius rotate laterally with the result that the palms come to face forwards; and the big toe and tibia rotate medially with the result that the soles face backwards—actually downwards. The elbow and knee flex in opposite directions. The front of the upper arm, forearm, and palm of the hand correspond to the back of the thigh, leg, and sole of the foot. If you place the palms of your hands on your knees, the bones of the lower segments of your limbs will occupy nearly equivalent positions.

Bony Landmarks. The following bony parts should be located on the skeleton and palpated on the living model, which will likely be yourself or a fellow student: The *anterior superior iliac spine;* the *tubercle* at the widest part of the iliac crest, 2½ inches from the spine; the *tubercle*, *crest*, and *symphysis* of the pubis; the *pubic arch* and the *ischial tuberosity* on which you sit (*fig. 373*).

A line drawn horizontally from the pubic tubercle will pass through the head of the femur below the midinguinal point and through the upper end of the *greater trochanter.* The greater trochanter lies about four inches below the tubercle on the iliac crest. Grasp it between your fingers and thumb. It is covered with the aponeurosis of the Gluteus Maximus and Tensor Fasciae Latae; so, it is not subcutaneous but subaponeurotic. It is palpated with difficulty when you stand on one leg, but with ease when you stand or lie down with legs well separated, for the aponeurosis is then relaxed. The *body of the femur* is deeply buried in muscles and is obliquely placed, as is evident from the fact that the heads of the femora of opposite sides are separated by the width of the pelvis while the condyles of

opposite sides touch or almost touch at the knees. The *adductor tubercle*, through which the lower epiphyseal line runs, is readily felt on pressing downwards and laterally at the upper part of the medial condyle. When the knee is flexed, the anterior parts of the *femoral*

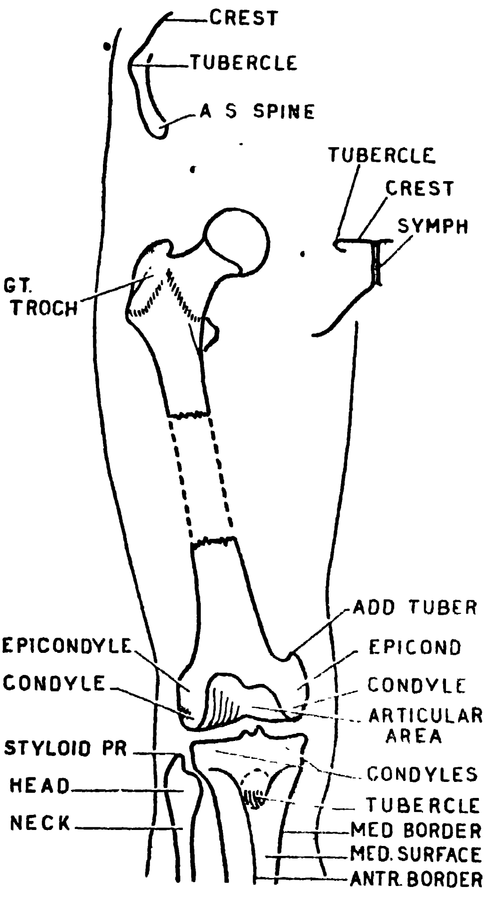


FIG. 373. Bony Landmarks of the thigh.

condyles can be felt and much of the articular surface. The *epicondyles*, lying at the centers of the posterior "discs" of the condyles (*fig. 475*), are readily located. The medial epicondyle is ¾" below the adductor tubercle. Palpate the flat, subcutaneous *medial surface of the tibia* and the *anterior and medial borders* that limit it. Then follow the medial surface upwards on to the *medial condyle of the tibia*, and follow the anterior border to the *tubercle of the tibia*. The *patella* is easily moved from side to side when the limb is straight and the extensors of the knee are relaxed, as when you bend over a basin or when you rest your heel on a chair while sitting on another chair, and much of its posterior articular surface is then palpable. Place the fingers behind the lateral aspect of the knee and palpate the rounded *head of the* fibula, the *neck* supporting it and the *styloid process* (apex) in which it culminates.

Superficial Structures. THE LAYERS OF THE SKIN, both dermis or true skin and epidermis, are thick and tough on exposed surfaces that are subject to pressure or friction, such as the dorsal aspect of the neck and trunk, the buttock, the lateral aspects of both limbs, the ischial region, the palm, the bearing points of the sole of the foot; and they are thin where they can be protected, as on the ventral (or flexor) aspects of the neck and trunk, flexor and medial aspects of the arm and forearm, thigh and leg, and on the dorsum of the hand and foot.

THE SUPERFICIAL FASCIA of the lower limbs is continuous with that covering the body generally. On the front of the thigh it is continuous with the adipose layer of superficial fascia of the abdomen (Camper's fascia). The deep or membranous layer of the superficial fascia of the abdomen (Scarpa's fascia) is attached to the deep fascia of the thigh a finger's breadth below the inguinal ligament (Poupart's ligament); more medially it is attached along an oblique line that runs parallel and lateral to the spermatic cord, from the pubic tubercle to the pubic arch, where it is continuous

with the corresponding layer of fascia (Colles' fascia) in the perineum (*fig. 481*).

The amount of fat over bony points, such as the acromion, olecranon, knuckles, and patella and under skin creases, is generally reduced; over the ischial tuberosity and the heel the fat is imprisoned in much fibrous tissue. There is no subcutaneous fat in the eyelid, auricle, penis, and scrotum. On the buttocks large quantities of fat may be deposited; in the Bushmen of South Africa, the quantity is enormous.

THE DEEP FASCIA is necessarily either absent or very thin and areolar over the thorax and abdomen, as is fascia over such organs as the bladder and rectum which require to expand and contract. But, where it forms tubular coverings for the neck and limbs, it is strong. It is especially strong in the lower limb. The portion enveloping the thigh is called the **fascia lata.** According to rule, the fascia lata is attached above and below to all the exposed bony and ligamentous parts it encounters; thus: *above*, it is attached round the limb to the anterior superior spine, the inguinal ligament, body of the pubic bone, the pubic arch, ischial tuberosity, sacro-tuberous ligament, and as the gluteal fascia it is attached to the sacral spines and to the outer lip of the iliac crest. *Below*, it is attached in front to the condyles and tubercle of the tibia and to various ligaments and tendons around the knee; *behind*, it is continuous with the popliteal fascia. It is extremely strong laterally because in between two thin layers of more or less circularly disposed fibers there runs a broad band of coarse vertical fibers called the **ilio-tibial tract** or **band** (p. 395). This tract is the conjoint aponeurosis of the Tensor Fasciae Latae (Femoris) and Gluteus Maximus.

The Long Saphenous Vein ascends throughout the length of the limb, in the subcutaneous fat. Below the knee it is conspicuous in the living, hence the name (Saphenes, derived from the Arabic = visible). It can be seen beginning at the medial end of the dorsal venous arch of the foot, passing in front of the medial malleolus, crossing the lower third of the medial surface of the tibia, and following half-an-inch behind its medial border as far as the knee. At the knee

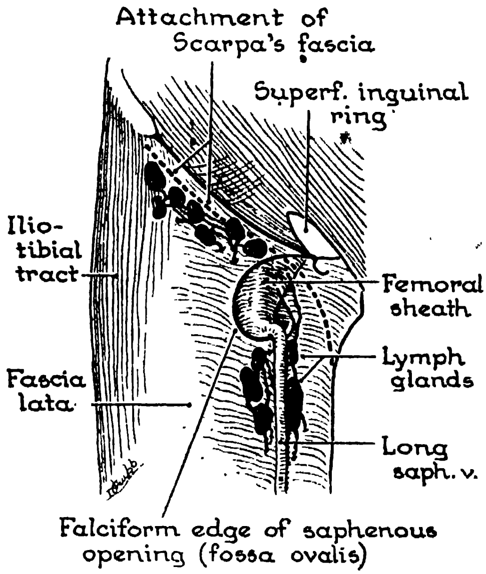


FIG. 374. Saphenous opening; long saphenous vein joining the femoral vein within the femoral sheath; lymph glands; and the attachment of Scarpa's fascia.

it is found on incising a hand's breadth (or slightly more) behind the medial border of the patella. From there it takes a straight course up the thigh to the femoral vein which it joins about $1\frac{1}{2}''$ below the inguinal ligament.

It anastomoses freely with the short saphenous vein; it communicates along intermuscular septa with the deep veins; and it receives numerous tributaries including 3 *superficial inguinal veins* which accompany the 3 superficial inguinal branches of the femoral artery, namely,

(a) the *superficial external pudendal artery* which crosses in front of the spermatic cord to supply the scrotum; (b) the *superficial epigastric artery* which passes towards the navel; and (c) the *superficial circumflex iliac artery* which passes laterally below the inguinal ligament.

The Saphenous Opening (Fossa Ovalis). The long saphenous vein has to pass through the fascia lata in order to reach the femoral vein; and evidently it is responsible for the large hole that exists, called the *saphenous opening*, for only in man is there such an opening in the fascia and only in man does the saphenous vein ascend far above the knee. Further, the vein would seem to have dragged down the lower margin of the opening to its present level, for it commonly hooks over it. So, to find the lower margin of the opening, pass the handle of the knife behind the vein and carry it upwards till arrested. The saphenous opening is about 1½" long. Above, it reaches to the pubic tubercle. It is free and sharp both above and below. Its lateral border is crescentic or falciform, and it blends with some areolar tissue (cribriform fascia) that covers the opening; hence, it is not sharply defined. Its medial border is continuous with the fascia covering the underlying Pectineus and as such it passes behind the femoral vessels.

Lymph Glands. In the upper limb the lymph glands are situated at the elbow and axilla; in the lower limb they are situated at the knee and groin. Their relationships to the deep fascia are reversed: (a) those at the elbow (supratrochlear) being superficial; those at the knee (popliteal) being deep; (b) those at the axilla (axillary) being deep; those at the groin (inguinal) being superficial, except for 2 or 3 deep ones.

The central group of axillary glands can be palpated against the ribs; the superficial inguinal glands can be palpated against the fascia lata. The supratrochlear glands cannot be palpated in health; nor can the popliteal glands.

The Inguinal Glands (*fig. 374*) are in two groups, a superficial and a deep. The *superficial glands* are subdivided into (a) an upper horizontal group that lies parallel to the inguinal ligament below the attachment of the fascia of Scarpa to the fascia lata, and (b) a lower vertical group placed on both sides of the upper end of the long saphenous vein. The *deep glands*, one to three in number, lie on the medial side of the femoral vein, in and below the femoral canal.

The lower superficial inguinal glands receive all the superficial lymph vessels of the lower limb save for the few that, following the short saphenous vein, end in the popliteal glands. *The upper superficial inguinal glands* drain the regions supplied by the three superficial inguinal blood vessels; namely, the subcutaneous tissues of the anterior abdominal wall below the navel and of the penis and scrotum (vulva in the female and lowest part of the vagina) and of the gluteal region, perineum, and lower part of the anal canal, but not of the testis (nor of the ovary). *The deep inguinal glands* receive the deep lymph vessels of the limb. These follow the femoral vessels and include those draining the popliteal glands. They also receive the lymph vessels of the glans penis (or clitoridis). The inguinal lymph glands drain into the external iliac glands via the femoral canal and via several channels that pass in front of and lateral to the femoral sheath (*fig. 372*).

Cutaneous Nerves (*fig. 375*). The cutaneous nerves of the front of the thigh are derived from segments L. 1, 2, 3, 4.

The *lateral*, *intermediate*, and *medial cutaneous nerves of the thigh* and the (long) *saphenous nerve* are derived from the femoral nerve. They pierce the deep fascia along an oblique line that roughly marks the Sartorius. The posterior branch of the lateral cutaneous nerve

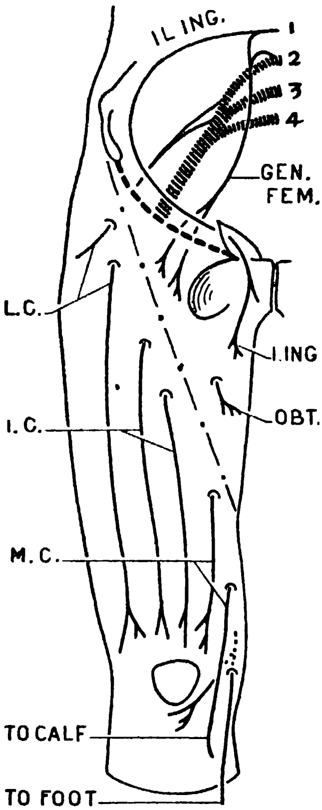


FIG. 375. Cutaneous nerves of the front of the thigh, above and below the line of the Sartorius.

passes to the gluteal region; the posterior branch of the medial cutaneous nerve extends to the calf; and the saphenous nerve extends half way along the medial border of the foot. The other branches remain above the knee. The *lateral cutaneous nerve* commonly arises independently from the lumbar plexus and enters the thigh close to the anterior superior spine. When it springs from the femoral nerve it enters at some distance from the spine. The *saphenous nerve* comes to the surface between the Sartorius and Gracilis, the width of the Sartorius behind the adductor tubercle. It gives off a *patellar branch* that pierces the Sartorius and arches downwards and laterally below the patella. A branch of the *obturator nerve* may become cutaneous at the middle of the thigh, medial to the Sartorius and extend to the calf—when present, it replaces the medial cutaneous nerve of the thigh.

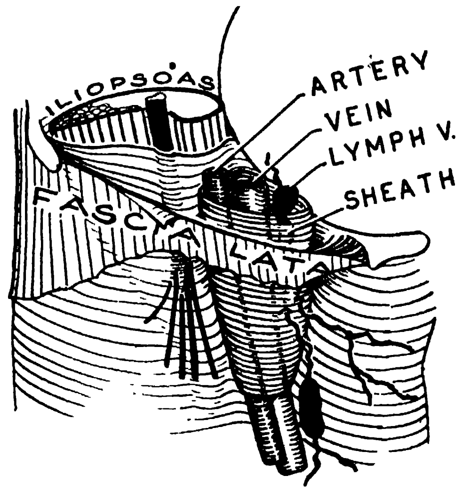


FIG. 376. The femoral sheath.

The area of the thigh overlying the femoral triangle (*p. 379*) is supplied by (a) the *ilio-inguinal nerve* which emerges through the superficial inguinal ring, and (b) by the femoral branch of the *genito-femoral nerve* (lumbo-inguinal n.) which enters the thigh as several twigs lateral to the femoral artery.

The Femoral Sheath (*fig. 376*). In the false pelvis the Iliacus and Psoas occupy an osseo-fascial pocket, the fascia of which is attached to the iliac crest laterally and to the pelvic brim medially. The two muscles pass behind the inguinal ligament into the thigh; so, naturally their

fascial covering goes with them. The part covering the Iliacus blends loosely with the inguinal ligament and with the fascia lata; this too is natural. The part covering the Psoas is separated from the inguinal ligament and from the fascia lata by the femoral vessels which here escape from the pelvis. The psoas fascia is continuous medially with the fascia that covers the Pectineus and extends upwards, in front of it, to the pelvic brim. The femoral artery, vein, and some lymph vessels are wrapped up in a prolongation of the extraperitoneal areolar tissue which envelops the external iliac vessels in the abdomen. This wrapping is the *femoral sheath.* The sheath is funnel-shaped; its lateral part lies behind the fascia lata, its medial part behind the saphenous opening. It has 3 compartments—a lateral one for the artery, a middle one for the vein, and a medial one partly occupied by lymph vessels. It is through the medial, partly occupied compartment that a femoral hernia may occur, and into it a distended femoral vein can bulge; this compartment is called the **femoral canal.**

THE FEMORAL RING is the mouth of the femoral canal. It is bounded *laterally* by the femoral vein; *posteriorly* by the superior ramus of the pubic bone covered with a coating of Pectineus and pectineus fascia; *medially* by the lacunar ligament and the conjoint tendon, both of which are attached to the pectineal line of the pubis; and *anteriorly* by the inguinal ligament and the spermatic cord.

To enlarge the ring in an emergency, (i.e., when reducing a femoral hernia), you dare not cut laterally into the vein; it would be useless to cut posteriorly on to the bone; you would require to cut either medially or anteriorly (*fig. 387*).

General Description of the Femur. The femur is the longest bone in the body, being a quarter of the stature, or about eighteen inches in a six foot man. It articulates above with the acetabulum, below with the tibia, and the patella plays on its lower end.

Its UPPER END presents for examination, a head, neck, greater trochanter, and lesser trochanter (*figs. 377, 378*). *The head* forms two-thirds of a sphere, and is directed medially, upwards, and forwards. It is much more secure in its socket than the head of the humerus, which forms one-third of a sphere and is directed medially, upwards, and backwards. *The neck* is pyramidal and obliquely placed. Its apex carries the head; its base abuts against the greater trochanter. In reality, the neck is the medially curved upper end of the shaft, but the fact is masked by the presence of the greater trochanter (*fig. 379*). The anterior aspect of the neck is flat and would be continuous with the anterior aspect of the shaft but for a broad, very rough, oblique line that runs from the upper end of the greater trochanter downwards and medially to a point a finger's breadth in front of the lesser trochanter. The roughness, called the *trochanteric line,* is due to the attachment of the massive ilio-femoral ligament and slightly to the aponeurosis of the Vastus Medialis. The posterior aspect of the neck is convex from above downwards. It is separated from the shaft by a very prominent and rounded ridge, the *trochanteric crest,* that unites the two trochanters. The neck is buttressed below by a rounded strengthening bar that ascends from the lesser trochanter. In the child the pelvis is narrow before the bladder and other viscera descend into the pelvis; so, the neck and shaft of the femur

are nearly in line with each other. As the pelvis widens the neck becomes more horizontal and the angle between neck and shaft becomes smaller (125° male). Because the female has a wider pelvis and shorter femur than the male, her femur is more oblique and the angle of the neck smaller. Obviously, a long horizontal neck increases the range of movement

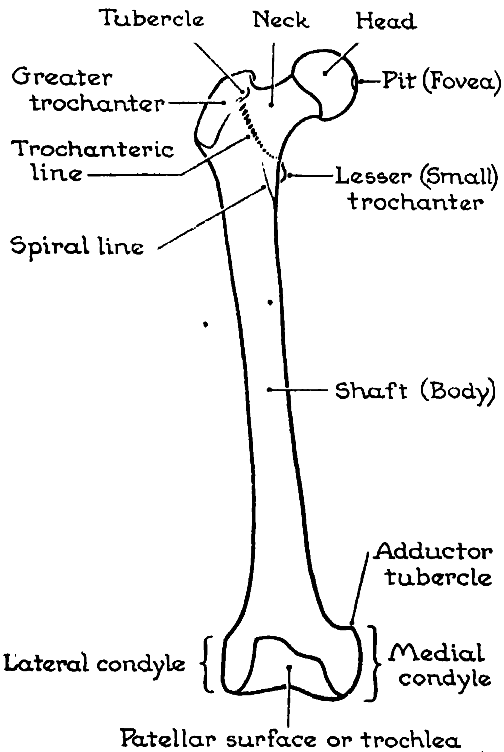


Fig. 377. The femur, front view.

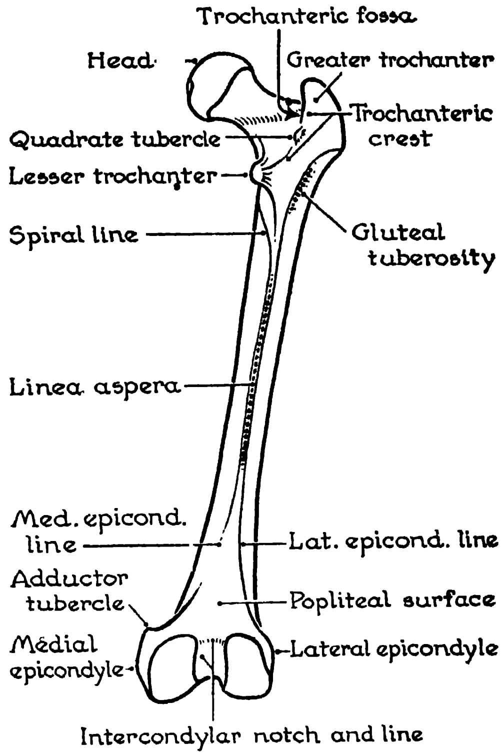


Fig. 378. The femur, posterior view.

of the limb. The *small* or *lesser trochanter* is the traction epiphysis of the Ilio-psoas. It is conical; it projects from the posterior surface of the bone; and it points medially. It does not possess the upward and forward inclination you might expect. From it, three lines radiate: one runs upwards and medially below the neck and buttresses it, as mentioned; the second runs downwards, gives attachment to the aponeurosis of the Pectineus (and to the upper part of the aponeurosis of the Adductor Brevis); the third runs upwards and laterally and forms the lower half of the (inter) trochanteric crest. *The great* or *greater trochanter* is the traction epiphysis, of the Glutei Medius et Minimus, (and also of the Piriformis, Obturator Internus and Gemelli, and Obturator Externus). The pull of the Gluteus Medius draws it upwards, medially, and backwards; so, its lateral surface is convex; its upper and posterior borders are free; and its highest point is its postero-superior angle. Its anterior and lateral aspects would be continuous with the corresponding aspects of the shaft but for the presence of a rouch line that marks the site of

fusion of the trochanter and shaft (*fig. 399*). A chisel driven along the upper border of the neck would remove the greater trochanter at this rough fusion line. The aponeurosis of the Vastus Lateralis is in part responsible for the rough line in front and laterally. A tubercle, called the *quadrate tubercle*, marks the site where this epiphyseal line crosses the (inter)trochanteric crest. The part of the crest above the tubercle is the posterior free border of the greater trochanter; the part below is the upwardly radiating line from the lesser trochanter. On the medial side of the greater tro-

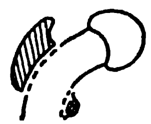


FIG. 379 The neck is the incurved shaft to which the trochanters are added.

chanter there is a circular depression, the *trochanteric fossa*, in which the Obturator Externus is inserted. From the fossa a shallow groove for the tendon of the Obturator Externus runs horizontally across the back of the neck (*fig. 410*).

THE SHAFT OR BODY is slightly bowed forwards. Its middle two-quarters are approximately circular on cross-section; its upper and lower quarters are enlarged and are oblong on cross section, the lower quarter being much the larger. A broad rough line, the *linea aspera*, stands out from the back of the middle two-quarters of the shaft like a pilaster. The linea aspera bifurcates above and below into diverging lines that bound triangular areas. The upper diverging lines are the *spiral line* and the *gluteal tuberosity.* The spiral line runs upwards and medially and is continuous with the (inter)trochanteric line; the gluteal tuberosity ascends towards the side of the greater trochanter and there becomes continuous with the epiphyseal line that runs around the root of the greater trochanter. The lesser trochanter projects from the triangle bounded by these lines. The lower diverging lines, the *medial* and *lateral epicondylar lines,* descend to the epicondyles and bound a flat triangular area, the *popliteal surface,* which is limited below by the condyles and a rough line, the *intercondylar line,* that separates the area from the intercondylar notch below. The lower inch of the medial epicondylar line curves abruptly medianwards to end in an upwardly projecting spine, the *adductor tubercle,* which is easily palpated in life.

The anterior and lateral aspects of the shaft give origin to the fleshy fibers of the Vastus Intermedius; the medial aspect is bare. The shaft, therefore, is smooth, and under the circumstances there is no purpose in describing medial and lateral borders The posterior border is the linea aspera. Many muscles and three intermuscular septa crowd on to it and on to its upward and downward prolongations; hence, their attachments are fibrous or aponeurotic, which accounts for the roughness of the border.

THE LOWER END OF THE FEMUR is divided into two large knuckles, the *medial* and *lateral condyles.* The hinder parts of the condyles project backwards like thick discs beyond the popliteal surface (*fig. 380*). Between the opposed surfaces of these discs is a U-shaped space, the *intercondylar notch,* the width and depth of the thumb. At the center or hub of the nonopposed surface of

each disc there is a marked fullness, the *epicondyle*, to which the medial and lateral ligaments of the knee joint are attached (*see fig. 479*). The condyles are covered with cartilage in front, below, and behind; the cartilages of the two sides meet in front in a V-shaped pulley, the *patellar surface* or *trochlea* in which the patella plays. The lateral lip of this pulley projects further forwards and further upwards than the medial lip. The lower parts of the condyles articulate with the tibia and semilunar cartilages during extension of the knee; the hinder parts during flexion.

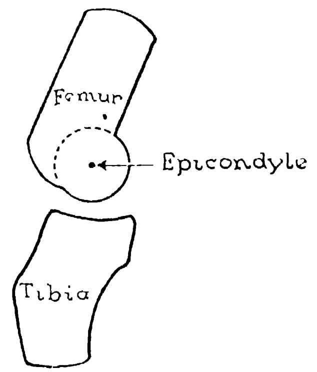


FIG. 380 A disc-shaped condyle and epicondyle

ORIENTATION. The condyles of the femur rest on the tibia as on a horizontal platform. The head and neck are slightly in advance of the shaft, that is, they are directed forwards, as well as medially and upwards. The shaft does not lie in a frontal plane but is inclined fowards above.

EPIPHYSES. The *head* fits like a cap on a spike (*fig. 468*), as is the case with the upper end of the humerus. The epiphyseal line encircles the articular cartilage except below where it shaves it. The *greater trochanter* joins the shaft along a line flush with the upper border of the neck, as described above. The *lesser trochanter* has a thick scale-like epiphysis.

The epiphyseal line of the *lower end* of the femur bisects the adductor tubercle and runs through the intercondylar line, shaving the cartilage at the upper end of the back of both condyles and front of the lateral one. The lower epiphysis possesses four shallow hollows into which four tubercles from the diaphysis fit. This is a primitive mammalian character.

Quadrupeds walk with bent knees and, requiring greater security, have four deep pits into which four prongs fit (*fig. 381*).

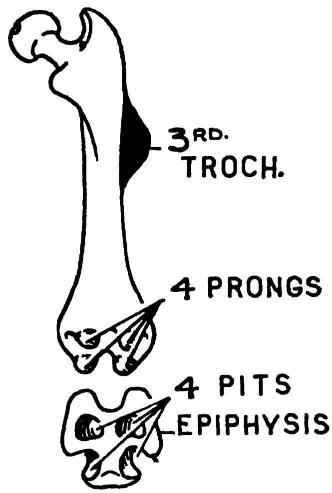


FIG. 381. Femur of muskrat showing two primitive mammalian characters.

At birth the lower epiphysis is an ossific nodule a quarter of an inch in diameter.

A *third trochanter*, also a primitive mammalian character, is constant in certain rodents and the horse, and may appear in any mammal including man as an enlarged gluteal tuberosity. *Platymeria*, or marked antero-posterior flattening of the upper part of the shaft of the femur, is common in primitive races.

THE FRONT OF THE THIGH

The Femoral Triangle of Scarpa. THE SIDES OF THE TRIANGLE. The base of

this triangular area, formed by Poupart's **inguinal** ligament, extends from the **pubic** tubercle to the anterior superior spine of the ilium. Its lateral side, formed by the medial border of the Sartorius, is likewise attached to the anterior superior spine and also to the notch below it. Its medial side is the medial border of the Adductor Longus, whose

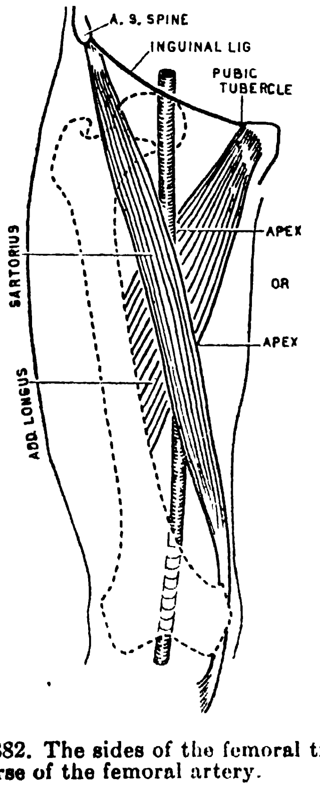


Fig. 382. The sides of the femoral triangle: The course of the femoral artery.

flattened tendon, ¾″ wide, arises from the front of the body of the pubis and reaches as far laterally as the pubic tubercle (*fig 382*). Geometrically, the lateral border of the Adductor Longus should be regarded as forming the medial side of the triangle, but it is more usual to select its medial border and, therefore, to include the Adductor Longus within the triangle. The apex is variously 4 or 6 inches below the inguinal ligament

according to whether the point where the Sartorius crosses the lateral or the medial border of the Adductor Longus is selected.

The Central and Dominant Structure within this triangular frame is the *femoral artery*. It begins where the external iliac artery ends; that is, midway between the symphysis pubis and the anterior superior spine, commonly called the *midinguinal point*. It leaves the

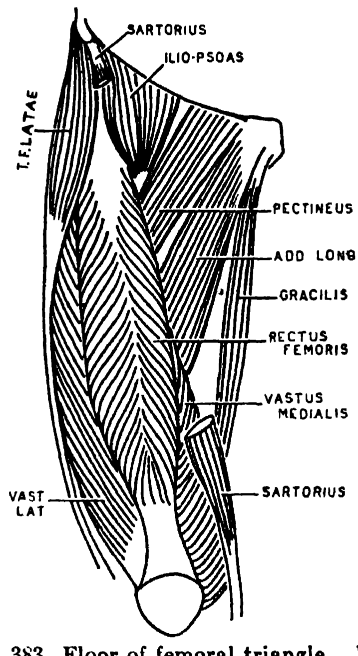


Fig. 383. Floor of femoral triangle. Walls of subsartorial canal.

smaller triangle, defined above, at its apex; that is, where the Sartorius crosses the lateral border of the Adductor Longus, four inches below the inguinal ligament, and enters the subsartorial or adductor canal of Hunter. It follows, then, that only its upper four inches lie exposed within the undissected triangle; the succeeding six inches, or remainder of the artery, travels through the subsartorial (adductor) canal.

The Floor of the Triangle is a trough or gutter of which the medial

sloping wall is formed by the Pectineus and Adductor Longus; the lateral sloping wall by the Ilio-Psoas and Vastus Medialis (*fig. 383*). The bottom of the trough is where these four muscles are attached to the femur (*fig. 384*). The *Ilio-Psoas* is inserted into the lesser trochanter; the *Pectineus* into the pectineal line that descends from the lesser trochanter to the linea aspera; the *Adductor Longus* into the linea aspera itself; the *Vastus Medialis* also gains attachment to the linea aspera, and above the linea aspera it gains attachment to the spiral line, which winds upwards and medially in front of the lesser trochanter, and to the trochanteric line. Each of these four attachments is fibrous, so, each causes a marking on the femur. If you are wise, you will define and clean the attachments of these and other tendons and aponeuroses as you meet them, and identify their markings on the skeleton. So doing greatly simplifies the work, and converts the drudgery of learning bones and muscles into an intelligent appreciation of them (*figs. 410, 413*).

The Contents of the Triangle (*fig. 385*). *The Femoral Artery* happens to run along the bottom of this trough—along a *boundary line* that separates two independent motor nerve territories. The obturator nerve supplies the muscles of the medial territory; the femoral nerve those of the lateral territory. You may, therefore, run your knife down the entire course of the artery without fear of damaging any motor nerve, for no motor nerve crosses it—save the nerve to the Pectineus. Truly, the nerve to the Pectineus arises from the femoral nerve and crosses the femoral artery, but it crosses it posteriorly at a high level.

The Profunda Femoris Artery may arise from the lateral aspect of the femoral artery at the level of the inguinal ligament, in which case two main arteries enter the limb; or it may arise four inches below the inguinal ligament, in which case but one artery traverses the femoral triangle; usually (75 per cent of cases, Quain), it takes origin between one and two inches below the ligament. It is only slightly smaller than the continuation of the femoral artery itself, and is therefore no mean vessel.

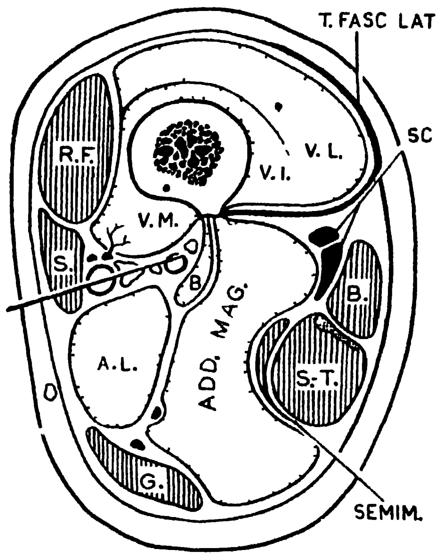


FIG 384 Cross section of thigh near apex of the femoral triangle showing (a) attachments of muscles to the linea aspera; (b) six muscles (hatched) that span the femur, and (c) that a bullet might penetrate the femoral and profunda femoris vessels

The *Femoral Vein* lies medial to the femoral artery in the femoral sheath, but lies behind the artery at the apex of the triangle; so do also the profunda artery and vein; all four vessels being almost inseparably united in a tough areolar sheath. A stab, therefore, or a bullet wound at the apex of the triangle would penetrate in succession all four vessels—only vessels of any magnitude conveying blood to or from the more distal parts of the limb. From before backwards they are—femoral artery, femoral

vein, profunda vein, and profunda artery (*fig. 384*).

The Femoral Nerve enters the thigh slightly lateral to the artery (*fig. 386*); but in the thigh it has almost no existence, for within an inch of its crossing the inguinal ligament it breaks up like a "cauda equina" into numerous motor and sensory strands. Two of these follow the artery, closely applied to its lateral

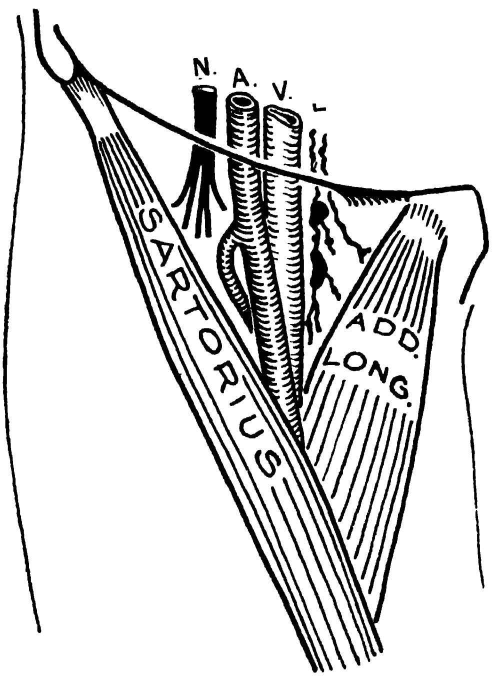


FIG. 385. The contents of the femoral triangle.

side, into the subsartorial canal; one, the *nerve to the Vastus Medialis* is motor; the other, the *saphenous nerve*, is sensory. Only one motor strand, the *nerve to the Pectineus*, actually crosses the artery; and it crosses posteriorly. How can this be? Is not the Pectineus an adductor muscle, and should not the obturator nerve supply it? Probably it is a composite muscle, having a double origin and a double nerve supply—femoral and obturator. The obturator branch, however, is commonly absent. The greater part of the Pectineus may be regarded as a medial extension of the Ilio-psoas. Functionally, it is to be grouped with the adductors.

At times, the adjacent borders of the Pectineus and Adductor Longus fail to lie in contact with each other, consequently the *Adductor Brevis* appears in the gap between them and assists in the formation of the medial sloping wall of the gutter; and the *anterior branch of the obturator nerve*, which passes in front of the Adductor Brevis, appears in the triangle Through the lower end of the

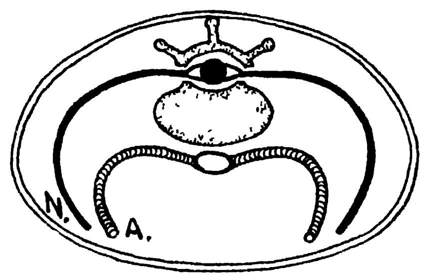


FIG. 386 The origins of the femoral nerve and artery account for their relative positions.

gap between Pectineus and Adductor Longus the profunda femoris artery and vein pass (*fig. 389*). The *medial femoral circumflex* branch of the profunda artery passes backwards and leaves the triangle between Pectineus and Ilio-Psoas, while the *lateral femoral circumflex* branch passes laterally through or behind the branches of the femoral nerve, disappears under cover of the muscles that arise from the anterior superior and anterior inferior iliac spines (namely the Sartorius and Rectus Femoris), and breaks up into three terminal branches.

The femoral artery lies in front of the Psoas tendon. But the Psoas tendon is hardly wider than the artery; so, there is no room on it for either the femoral

nerve or the femoral vein. They, therefore, must lie in front of other structures. The nerve lies lateral to the artery and, therefore, in front of the Iliacus; and the vein lies medial to the artery and, therefore, in front of the Pectineus; and the lymph vessels accompany the vein. Hence, it may be said that the artery is separated from the hip joint by the strong, tough tendon of the Psoas; the nerve by the thickness of the fleshy Iliacus; the vein and the lymph vessels by the thinness of the fleshy Pectineus. Push the blade of the knife through these intervening structures in order to verify these statements (*fig 387*).

The Subsartorial Canal or the Adductor Canal of Hunter. If Scarpa's Femoral Triangle is an open trough with sloping sides, then Hunter's Adductor Canal is to be regarded as the narrow outlet of this trough roofed in by the Sartorius and thereby converted into an intermuscular tunnel, triangular on cross-section. It begins, therefore, 4 inches below the inguinal ligament and ends 4 inches above the adductor tubercle (*fig. 388*). Through it run the femoral vessels and the saphenous nerve.

The Sartorius arises side by side with the inguinal ligament from the tip of the anterior superior iliac spine (and also from the notch below). As the area of a cross section of the Sartorius is greater than the surface of the ilium from which it arises, it follows that its origin must be fibrous—at least in part. It is inserted into the medial surface of the tibia below the level of the tubercle (*fig. 417*). It comes into contact with the medial condyle of the femur immediately behind the adductor tubercle and from there downwards to its insertion it rubs against resistant structures (viz., medial condyle of the femur, capsule of the knee, medial condyle of the tibia, medial ligament of the knee, and the tendons of the Gracilis and Semitendinosus), therefore, its fleshy fibers give place to tendon. Between it and the tendons of the Gracilis and Semitendinosus a bursa is interposed.

Observations. If you measure, you will find that the fleshy part of the muscle is 18 inches long; and if you, look you will see that its fibers run longitudinally. It should, therefore, on contracting, shorten by about 6 inches, that is by

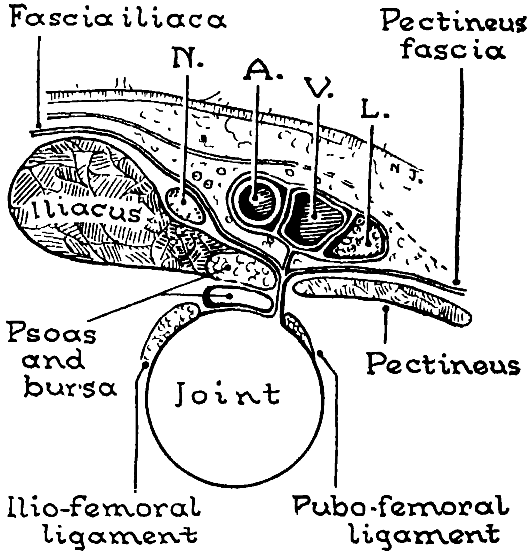


FIG. 387. The relationship of the femoral vessels and nerve to the hip joint.

about one-third of its fleshy length of 18 inches. If you measure on your own extended limb the distance between the points of origin and insertion of the Sartorius, and then while sitting down, approximate the insertion as close to the origin as possible, and measure again, you will find that the distance has been reduced by six inches. This explains why the Sartorius, which is the longest muscle in the body, requires so long a fleshy belly and why it needs a loose sheath in which to shorten and to lengthen. When origin and insertion are approximated,

the hip joint will be found to be flexed, abducted, and laterally rotated; the knee joint to be flexed and medially rotated. The limbs are brought into the position that the tailor (sartor—a tailor) traditionally assumes when at work.

Nerves. The Sartorius is supplied by the femoral nerve in its upper third. The lateral, the intermediate, and the medial femoral cutaneous nerves sometimes pierce it and the patellar branch

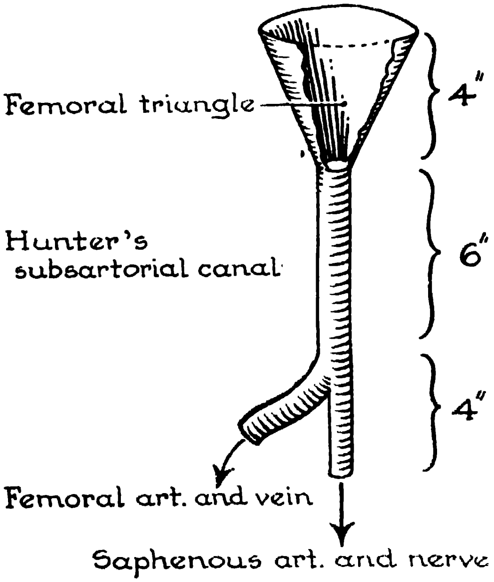


FIG. 388. The femoral "trough" and subsartorial "tunnel" and its two outlets.

of the saphenous nerve constantly pierces it.

The Walls of the Canal. Except for two or three inches at each end, the Sartorius may be excised or may be displaced laterally. It will then be evident that, were there no Sartorius, there would be no femoral triangle and no subsartorial (adductor) canal but merely a long V-shaped trough whose medial and lateral sloping walls meet on the femur from the level of the lesser trochanter above to the adductor tubercle below. Connecting these two bony points are: the pectineal line, linea aspera, and the medial epicondylar line. The muscles of the lateral sloping wall of this long trough are: Ilio-Psoas, Vastus Medialis, and Rectus Femoris. They are supplied by the femoral nerve. The muscles of the medial sloping wall are 5 in number. They are adductors and, with the exception of the Pectineus, are supplied by the obturator nerve. Three of them (the Adductores Pectineus, Longus, and Gracilis) have a continuous curved origin from the pubic bone. [The *Pectineus* arises by fleshy fibers from the superior ramus of the pubis just in front of the pectineal line and from Cooper's ligament. This origin extends from the ilio-pubic eminence laterally to the pubic tubercle medially; the tendon of the *Longus* arises from the body of the pubis for ¾ of an inch medial to the tubercle, to be succeeded by the aponeurosis of the *Gracilis,* which being 2″ wide extends down the margin of the pubic arch.] These three muscles spread out fanwise as they descend to their aponeurotic insertions. As a result, the Brevis appears in the interval between Pectineus and Longus; the Magnus appears between Longus and Gracilis (*fig. 389*). The Gracilis is inserted into the medial surface of the tibia deep to the Sartorius, and it lies immediately behind the Sartorius as the two cross the medial femoral condyle. The Magnus descends to the level of the adductor tubercle. (*Fig. 410*).

The Contents of the Canal. In the furrow between these two motor nerve territories run the femoral artery and its branch, the *saphenous artery.* The course of these may be mapped out by a line joining the midinguinal point to the adductor tubercle. The upper two-thirds of this line maps out the course of the femoral artery, the lower third that of the saphenous artery. The femoral

artery becomes the popliteal artery by passing through a gap or hiatus in the insertion of the Magnus 4 inches above the adductor tubercle. Here fleshy fibers of the Vastus Medialis prevent the artery from coming into direct contact with the femur. The saphenous artery, more often springing from the descending genicular artery than from the femoral direct, passes in front of the remainder of the Magnus and becomes cutaneous at the medial side of the knee between the tendons of the Sartorius and Gracilis. These are the only two representatives of the muscles supplied by the femoral and obturator nerves respectively that pass below the knee.

The Nerve to the Vastus Medialis accompanies the femoral artery into the canal; and as its duty is to supply the muscle of the lateral wall of the canal it remains lateral to the artery *The Saphenous Nerve* accompanies the femoral artery through the femoral triangle and subsartorial canal; then it accompanies the saphenous artery to the surface, and thereafter it accompanies the long saphenous vein through the leg and ends ultimately half way along the medial border of the foot. Evidently it must cross the artery from lateral to medial side in some part of this course. It does so in the canal; and it crosses anteriorly. The saphenous nerve comes to the surface between femoral nerve territory and obturator nerve territory, the representative muscles being the Sartorius and the Gracilis.

It is of interest to note that in certain mammals the saphenous nerve, artery, and vein are companion structures that emerge from the canal and pass down the medial side of the leg to the foot. In man all three are present, but only the nerve persists in the old route. The artery is but a small branch that ends subcutaneously below the medial condyle. The vein is peculiar in man in not following the artery and nerve into the subsartorial canal to end in the distal part of the femoral vein, but in extending up the thigh and creating for itself a hole (saphenous opening) in the deep fascia through which it gets access to the proximal part of the femoral vein. True,

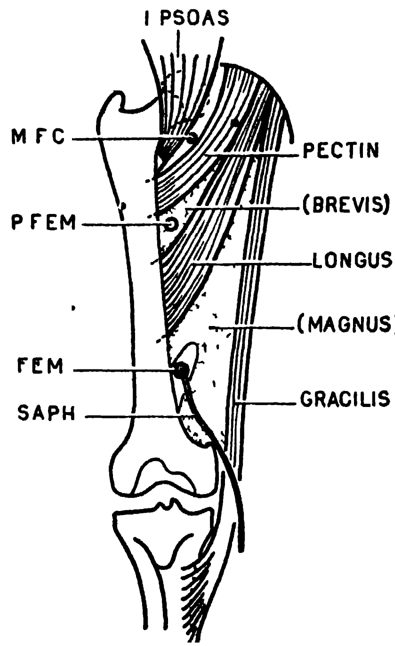


FIG. 389. The muscles posterior to the femoral and saphenous arteries Three adductor muscles spread fanwise to their insertions. Arteries course between them.

it sends a communicating branch via the old route to the lower end of the femoral vein.

The structures entering the subsartorial or adductor canal are:

1. The femoral artery and vein.
2. The profunda artery and vein.
3. The nerve to the Vastus Medialis.
4. The saphenous nerve.

The structures leaving the canal are:

1. The femoral artery and vein.

2. The saphenous nerve, artery, (and vein).

The femoral vein lies medial to the femoral artery at the base of the femoral triangle, behind it at the apex of the triangle, and lateral to it where it passes through the opening in the Adductor Magnus into the popliteal fossa. Throughout, the two vessels are so firmly bound together in a common sleeve that the one cannot move without the other. The profunda artery and vein (or veins), almost as large as the femoral vessels themselves, soon disappear through the gap between the Adductor Pectineus and Adductor Longus.

The nerve to the Vastus Medialis passes far into the canal but, of course, it remains lateral to the artery. The saphenous nerve traverses the canal and crosses the artery.

An incision made from one end of the femoral artery to the other will not divide a motor nerve. The saphenous nerve will be cut and, more superficially, the medial cutaneous nerve of the thigh will be cut, but both of these are sensory nerves.

The Regions of the Thigh. THEORETICALLY, the thigh may be regarded as divided into four regions, each separated from its neighbour by an intermuscular septum, and each containing a group of muscles and their nerve (*fig. 390*). The *anterior region*, supplied by the femoral nerve, would contain the flexors of the hip and also the extensors of the knee; the *posterior region*, supplied by the sciatic, nerve would contain the extensors of the hip and also the flexors of the knee; the *medial region*, supplied by the obturator nerve, would contain the adductors of the hip; and the *lateral region*, supplied by the superior gluteal nerve, would contain the abductors of the hip.

ACTUALLY, this scheme is departed from in the following main respects: Of the three abductors, supplied by the superior gluteal nerve, two (the Glutei Medius et Minimus) do not descend beyond the greater trochanter—which is in fact their traction epiphysis—while the third, the Tensor Fasciae Latae, spans the femur and gains attachment to the front of the lateral condyle of the tibia and to the side of the patella by means of the ilio-tibial tract, which is incorporated between the circular layers of the fascia lata. It falls to the remaining three groups, supplied respectively by the femoral, obturator, and sciatic nerves, to surround the femur. This they do, but not equally. The anterior muscles envelop and monopolize the shaft of the femur, except along its posterior border which alone is free and available to the medial and posterior muscles and to all intermuscular septa. The attachments of the muscles to this restricted border are necessarily aponeurotic; hence, the roughness of the border and its name—the *linea aspera.*

In addition to the ilio-tibial tract, six muscles in all pass from the hip bone (os coxae) to the tibia or fibula; that is to say, they span the femur but they find no accommodation on it. Of these six, one belongs to the medial group, two to the anterior group, and three to the posterior group (*fig. 384—hatched muscles*).

The Quadriceps Femoris. Of the *femoral nerve group* of muscles (Ilio-Psoas, Pectineus, Sartorius, and Quadriceps Femoris) the *Quadriceps Femoris* remains to be described. The four heads of this very powerful muscle are the Rectus Femoris and the 3 Vasti (Medialis, Lateralis, and Intermedius). Of these the Rectus arises from the ilium; the 3 Vasti arise from the shaft of the femur.

This enormous muscle is inserted into a small area of bone, namely, to the

intermediate part of the tubercle of the tibia and to the two diverging lines ascending from it; so, it follows that the insertion must be tendinous. Where the tendon plays across the front of the lower end of the femur a sesamoid bone, the *patella*, is developed. The portion of the tendon distal to the patella is called the *ligamentum patellae*. The patella does not lie in front of the knee joint--in front of a space where it would be functionless—but, like other sesamoid bones, it plays upon the end of a bone.

The Ilio-Psoas acts on the hip joint, the Vasti on the knee joint, the Rectus both on the hip and the knee. These three may be compared and contrasted with the Coraco-brachialis, Brachialis, and Biceps which act upon the shoulder and elbow joints.

The Rectus Femoris (*fig. 383*) has a tendinous origin that is practically co-extensive with, and is immediately superficial to, the iliac attachment of the ilio-femoral ligament of the hip joint, both being attached to the anterior inferior iliac spine and to the acetabular margin for an inch behind it. There is a slight interval between the spinous and acetabular origins of the Rectus which are known respectively as the *straight* and *reflected heads* (*fig. 467*).

Note. If a finger be passed behind the lateral border of the Rectus and carried upwards until arrested, the finger nail will, of course, lie on the ilio-femoral ligament of the hip joint. Moreover, the finger is working in an *internervous line*, in the boundary line between muscles supplied by the femoral nerve and muscles supplied by the superior gluteal nerve. In fact, if an incision be made vertically downwards from the anterior superior spine, the Sartorius may be pulled medially, the Tensor Fasciae Latae laterally, and the anterior inferior spine exposed; thereafter, the Glutei Medius et Minimus may be pulled backwards, the Rectus forwards, and the hip joint exposed. The posterior branch of the lateral cutaneous nerve of the thigh and (tho transverse and ascending) branches of the lateral circumflex vessels will be encountered, but no motor nerve crosses this line.

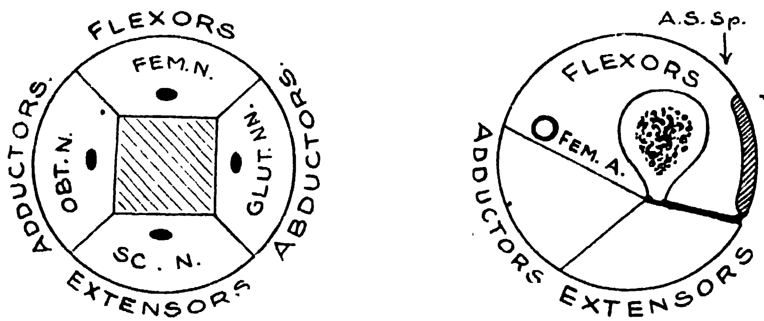


FIG. 390. The regions of the thigh: theoretical and actual.

The tendinous insertion of the Rectus is attached to the upper border of the patella; some fibers, however, pass across the front of the patella and join the ligamentum patellae. In a fractured patella these fibers may be torn below the level of the fracture, turn in, and prevent union of the fragments.

Though the Rectus Femoris and the Sartorius arise and are inserted close together, the course they take and consequently their actions and internal structure or *architecture* are very different.

The Sartorius has been discussed p. 383. The duty of the Rectus Femoris is to assist in extending the knee. This it does by pulling on the patella. The patella can make an excursion of about 2 inches—this you can decide on your own limb—so, the fibers of the Rectus require to be only 4–6 inches long. It is unnecessary for them to run through the length of the muscle. They arise from the front of the tendon of origin, diverge from each other in bipennate manner, turn round the borders of the muscle, and end behind in the tendon of insertion. By this arrangement the Rectus increases the number of its fibers and therefore its power; but owing to the shortnessof its fibers its range of contraction is not great. The Rectus also assists in flexing the hip joint; and next to the Ilio-psoas is its most powerful flexor, but its orgin is so close to the acetabulum that no great increase in length of fiber is necessary.

The Three Vasti clothe the shaft of the femur. The Vastus Intermedius arises by fleshy fibers from the anterior and lateral aspects. No muscle arises from the medial aspect, but the Vastus Medialis overlies it. The Vasti Lateralis et Medialis arise largely by aponeuroses from the lateral and medial lips respectively of the linea aspera as well as from the upward and downward continuations of these lips: that is to say, above they diverge along the gluteal and spiral lines respectively, pass below the greater and lesser trochanters respectively, and meet in front on the (inter)trochanteric line. Below they diverge along the lateral and medial epicondylar lines, from which and from the respective intermuscular septa they arise. And, of course, they are in part responsible for these lines.

For reasons given with the knee joint, the precise insertions of the Vasti are worth noting (p. 462). The Vasti Medialis et Lateralis are continuous at their insertions, and they occupy a plane between the Rectus Femoris and Vastus Intermedius, and all four are inserted into the base of the patella. The Medialis is attached to the upper ⅔ of the medial border of the patella and only slightly to the base, while the Lateralis is attached to the remainder of the base and only slightly to the lateral border. The fibers of the medial and lateral Vasti are obliquely set and numerous. They arise largely by aponeuroses and are inserted by aponeuroses.

When the fleshy fibers of the Vastus Medialis are detached from the tendon of the Adductor Magnus and from the medial intermuscular septum, the *descending (highest) genicular artery* is seen descending on the septum to reach the joint. It is the last branch of the femoral artery, and it often has a common origin with the saphenous artery.

Distribution of the Femoral Nerve (L. 2, 3, 4). THE MOTOR DISTRIBUTION (*fig. 463*). *The Psoas* is supplied by the roots of the femoral nerve. *The Iliacus* is supplied while in the iliac fossa. *The Pectineus* is supplied near its lateral border by a twig that passes behind the femoral sheath. *The Sartorius* and *Rectus Femoris* are each supplied by a branch whose twigs enter them from 3–6 inches from the anterior superior spine. *The Three Vasti* receive short, stout branches at their upper ends. The Vasti Medialis and Lateralis each receive one long branch also, which enters their respective anterior borders near their middles. The long branch to the Lateralis follows the descending branch of the lateral femoral circumflex artery along the anterior border of the muscle and serves as a

guide to it. And, it lies lateral to the artery, as you would expect from a consideration of the locations of the parent stems. The long branch to the Medialis runs along the lateral border of the femoral artery far into the adductor canal. A slender twig runs on the femur along the medial border of the Intermedius and supplies its most distal fibers, called the *Articularis Genu*. These fibers are attached to the synovial capsule of the knee. Their purpose is to retract the capsule during extension of the knee thereby preventing it from becoming nipped.

THE CUTANEOUS DISTRIBUTION. (*Fig. 375*).

THE VASCULAR DISTRIBUTION. The femoral nerve supplies the part of the femoral artery in the subsartorial canal, but not the part in the femoral triangle. This is supplied by an extension of the plexus on the common and external iliac arteries.

THE ARTICULAR DISTRIBUTION. The nerve to the Rectus Femoris sends a twig to the capsule of the hip joint. The nerves to the three Vasti send twigs to the capsule of the knee joint and the saphenous nerve sometimes does so.

GENERAL DESCRIPTION OF THE HIP BONE

The hip bone (os coxae) is a large irregular bone which, because it bears no resemblance to any common object, is often called the innominate bone. The hip bones of opposite sides articulate with each other in front at the *symphysis pubis* and with the sacrum behind at the respective sacro-iliac joints. The two hip bones, the sacrum, and the coccyx comprise the pelvis. When studying these bones you should hold them in correct orientation (p. 331).

COMPONENT PARTS. The hip is composed of three elements—ilium, ischium, and pubis. These three meet at the cup-shaped cavity for the head of the femur, called the *acetabulum*, and are there united by a triradiate cartilage until the sixteenth year, when fusion takes place (*fig. 391*).

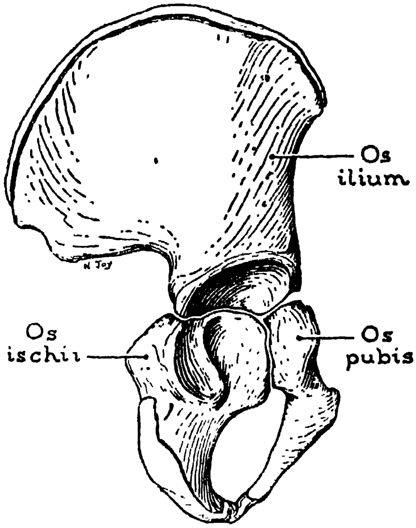


FIG. 391. A young hip bone.

The *ilium*, or bone of the flank, is a flat bone; the *ischium*, or bone of the hip, and the *pubis*, or bone covered with hair at puberty, are irregular V-shaped bones. The ilium lies above the acetabulum; the ischium behind and below; the pubis in front and below. The pubis and ischium surround a large oval foramen, the *obturator foramen;* this lies below the acetabulum and is closed by a membrane, the *obturator membrane,* except in its upper part where the obturator vessels and nerve escape from the pelvis. The site of fusion of ilium with pubis is conspicuous in front of the

pelvic brim as the *ilio-pubic eminence;* **the** site of fusion of ilium with ischium within the pelvis (*fig. 329*) and on the posterior aspect of the bone is marked by a detectable line; a constriction denotes where pubic and ischial rami fuse below the obturator foramen about the eighth year to form a conjoint ramus.

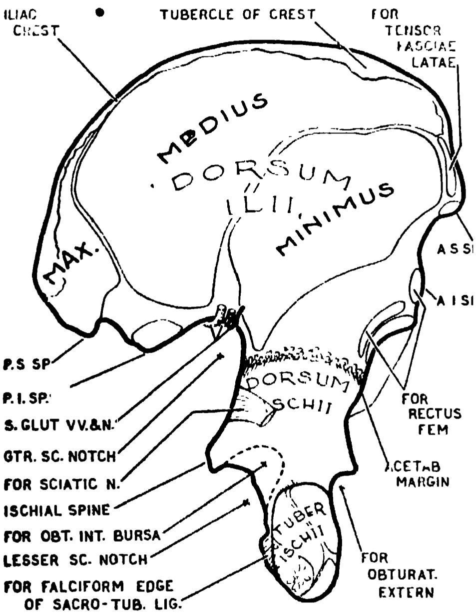


FIG. 392. The gluteal aspect of the hip bone.

SURFACES. The hip bone, considered as a whole, has two surfaces—an inner and an outer:

(1) The inner or pelvic surface is described on page 328.

(2) The outer surface is divisible into three regions—the gluteal aspect, the adductor aspect, and the acetabulum.

THE GLUTEAL ASPECT (POSTERO-LATERAL ASPECT) OF THE HIP BONE (*fig. 392*). This aspect is wide above and is there bounded by the whole length of the iliac crest. Below, it is narrow and forms the lower part of the ischial tuberosity. It can be subdivided into three obviously different areas: (1) above is the fan-shaped *dorsum ilii,* (2) below is the rough, oval *ischial tuberosity,* and (3) between these is a large quadrate area. the *dorsum ischii.* The dorsum ischii is bounded laterally by the acetabular margin, and medially by the margin of the greater sciatic notch which ends below in the ischial spine.

THE ADDUCTOR ASPECT (ANTERIOR ASPECT) OF THE HIP BONE. This comprises the anterior aspect of that part of the bone which surrounds the obturator foramen, exclusive of the acetabulum. It is limited above by the pelvic brim; medially by the symphysis pubis and medial border of the pubic arch; postero-inferiorly by the lateral border of the ischial tuberosity, and postero-superiorly by the iliopubic eminence. It comprises the entire outer aspect of the pubic bone and ischial ramus and the lateral surface of the ischial tuberosity (i.e., the pillar of bone supporting the acetabulum). It affords origin to the adductor muscles and attachment to the Rectus Abdominis, Pyramidalis, and aponeurotic sheath of the Rectus.

THE ACETABULUM is described on page 454.

The Ilium (os ilii) is fan-shaped, the handle of the fan being below, where the ilium joins the ischium and pubis. The upper border, the *iliac crest,* is arched and is sinuous like the clavicle of its own side, being convex forwards in its medial part, concave in its lateral. And, like the clavicle, it is subcutaneous, palpable throughout, crossed by cutaneous nerves, but not by muscles (there being no Platysma here); so, the deep fascia is attached to it. In front it ends in the rounded *anterior superior iliac spine* (A.S.Sp.), behind in the sharp *posterior superior iliac spine* (P.S.Sp.), and from its most lateral point (about $2\frac{1}{2}''$ behind

the A.S.Sp.) a broad *tubercle* projects downwards. The pull of the abdominal muscles creates a traction epiphysis on the crest. The *anterior border* extends from the anterior superior spine to the iliopubic eminence and is deeply concave. The concavity is subdivided into two nearly equal lesser concavities by the *anterior inferior spine*, which, being the site of attachment and pull of the straight head of the Rectus Femoris, possesses an epiphysis. The *posterior border* extends from the posterior superior spine towards the ischial spine. It is subdivided into two unequal concavities by the *posterior inferior spine* which lies at the posterior limit of the sacro-iliac joint. The upper concavity is slight; the lower one forms the upper part of the V-shaped *greater sciatic notch*.

Of the 2 surfaces of the ilium: (a) the *inner* is divided into—an iliac fossa, a tuberosity, an auricular surface, and an area within the true pelvis (*figs. 329 and 335*); and (b) the outer is the *dorsum ilii*.

THE DORSUM ILII or gluteal surface of the ilium is wavy, being convex in front in conformity with the shape of the iliac fossa and concave behind because of its relation to the auricular surface and tuberosity (*fig. 335*). This surface is crossed by three rough lines, the inferior, middle, and posterior *gluteal* (*curved*) *lines*, which give attachment to aponeuroses and subdivide the dorsum into 4 areas: the areas for the Gluteus Minimus and Gluteus Medius are extensive and equal; the restricted area remaining behind the Medius is for the Gluteus Maximus and slightly for the sacro-tuberous ligament; the restricted area between the Minimus and the acetabular margin has a broad linear marking for the iliofemoral ligament and reflected head of the Rectus Femoris.

The Ischium (os ischii) has 3 parts—a *body* adjoining the ilium, a *tuberosity* projecting downwards from the body, and a *ramus* (inferior ramus) passing from the tuberosity upwards and forwards below the obturator foramen.

THE BODY is triangular on cross-section and has 3 surfaces separated by 3 borders. The borders are parts of the margins of the (a) obturator foramen, (b) acetabulum, and (c) greater sciatic notch. The surfaces are: (a) medial or pelvic (p. 328), (b) lateral or acetabular (p. 454) and (c) gluteal or posterior.

The Gluteal Surface of the Body or "dorsum ischii" lies between the acetabular margin and the greater sciatic notch. Above, it is continuous with the dorsum ilii; below, with the ischial tuberosity. Together with a small portion of the ilium just above it, it forms a quadrate, slightly convex surface. This the sciatic nerve and other structures cross.

THE TUBEROSITY OR TUBER ISCHII is the oval mass of bone from which the hams arise; so, it is rough and has an epiphysis (*fig. 404*). It has a medial and a lateral border. The upper part of the medial border has playing across it the tendon of the Obturator Internus; so, it is smooth, concave, covered with a bursa, and forms part of the lesser sciatic notch. The lower part of the medial border is a rough line or crest for the attachment of the sacrotuberous ligament. The lateral border gives fleshy origin to the Quadratus Femoris. Between this and the acetabulum there is a deep groove occupied by the Obturator Externus.

It is convenient and sufficient to extend the term "tuberosity" to the entire mass of bone between the tuberosity, as described above, and the obturator foramen—that is, to the pillar of bone below

the acetabulum. The tuberosity, in this sense, is triangular on cross-section and has three surfaces—tuberosity proper (posterior), pelvic (medial), and adductor (lateral). This pillar of bone is variously described as the lower part of the body of the ischium and as the superior ramus; but, whatever its designation may be, its chief functions are to support the body when sitting and to give origin to the hams.

The *sciatic notches*, greater and lesser, extend from the posterior inferior iliac spine to the ischial tuberosity. They are separated from each other by a beak-shaped process, the *ischial spine*. This gives attachment to the sacrospinous ligament, and it is grooved below by the tendon of the Obturator Internus. A strong band (part of the sacrotuberous lig.) bridges the gap between the medial border of the tuberosity and the posterior superior spine; it affords origin to the Gluteus Maximus; and, with the sacrospinous ligament, it converts the sciatic notches into sciatic foramina (*figs. 335, 353*).

THE RAMUS OF THE ISCHIUM is a flattened bar that springs from the tuber ischii, making with it a V-shaped bend. By uniting with the inferior ramus of the pubis it forms the *conjoint ramus* of the ischium and pubis. The conjoint rami of the two sides constitute the *pubic arch*. Each conjoint ramus has two surfaces, an *inner* and an *outer*, separated by two borders, a *lateral* and a *medial*. The lateral is part of the obturator margin; the medial is part of the medial border of the pubic arch.

The Pubis (os pubis) (*fig. 393*) has 3 parts—a *body* lying medially, a *superior ramus* passing upwards and laterally from the body, and an *inferior ramus*, descending from the body and forming part of the pubic arch.

THE BODY is a squarish plate which articulates with its fellow at the symphysis. It has two surfaces: (a) a smooth *inner* or pelvic which supports the bladder and faces postero-superiorly, and (b) an *outer* which faces antero-inferiorly and is rough for tendinous attachments. Its *medial border* is the *symphysis pubis*. This is elliptical, covered with cartilage, and 1½″ deep. Its *upper border* is the pubic crest; this is about 1″ long, smooth and thick; it ends laterally at the *pubic tubercle*. Its *lateral border* is the margin of the obturator foramen. Lateral to the pubic tubercle the body is continuous with the superior ramus; below the level of the symphysis it is continued as the inferior ramus.

THE SUPERIOR RAMUS is a three-sided pyramid. The apex is continuous with the body medial to the pubic tubercle. The base forms a fifth of the articular part of the acetabulum and there fuses with the ilium and ischium, the site being marked above by the iliopubic eminence. The 3 borders are formed by 2 lines that diverge from the pubic tubercle: (a) one, the *pectineal line*, is that arc of the pelvic brim that extends from the pubic tubercle to the iliopubic eminence · the reasons for its sharpness are given on page 328; (b) the other line is the spiral *margin of the obturator foramen*. This margin begins at the pubic tubercle outside the pelvis and ends near the iliopubic eminence inside. The two ends of the spiral bound the inferior grooved surface of the ramus and account for two borders. The segment of the spiral that extends from the pubic tubercle to the acetabulum is a strengthening bar, called the *obturator crest*. The 3 surfaces are—pelvic, pectineal, and inferior. The pelvic surface is separated from the pectineal surface by the pectineal line; the pectineal surface is separated from the inferior surface by

the obturator crest. The pectineal surface is triangular; it extends from pubic tubercle to iliopubic eminence; and it faces antero-superiorly. The Pectineus arises from the whole length of the hinder part of this surface and overlies the anterior part. The inferior surface is the wide groove between the two ends of the spiral; in it run the obturator vessels and nerve.

THE INFERIOR RAMUS OF THE PUBIS is the body prolonged downwards for half an inch to join the ramus of the ischium at a constriction.

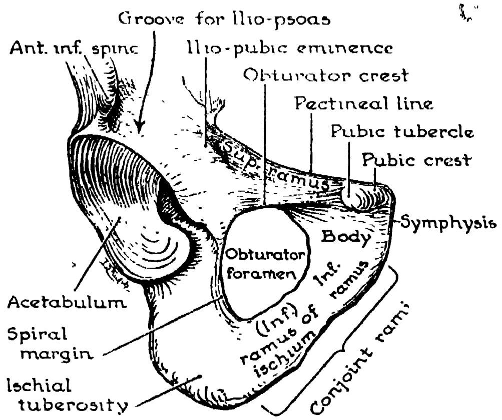


FIG. 393. The pubic bone, front view.

FUNCTION. When *sitting*, the superimposed weight of the body is supported by the ischial tuberosities; it is then the function of the pubic arch and bodies of the pubes to stabilize the ischia, preventing them from being forced together and from being forced apart. When *standing*, the weight is transmitted through the ilia and across the acetabula to the femora; it is then the function of the superior rami and the bodies of the pubes to act as a strut, preventing the ilia from being forced together; i.e., they perform the function of clavicles; in the specimen depicted in figures 333, 334 they failed to do so effectively.

THE GLUTEAL REGION

The gluteal region is bounded above by the iliac crest and below by the lower border of Gluteus Maximus. In studying this region full use should be made of the bony landmarks that obtrude themselves and of certain simple lines that connect them.

Bony Landmarks. The whole length of the *iliac crest*, including its anterior superior spine, tubercle, highest point, and posterior superior spine, is readily palpated. The iliac crest is palpable because it is subcutaneous, or in other words, because neither muscle nor tendon crosses it; and being subcutaneous the deep fascia of the region is attached to it. There is no deep fascia enveloping the abdomen. If there were, it also would be attached to the iliac crest. Branches of the posterior rami of the first 3 lumbar nerves cross the crest at the lateral border of the Sacro-spinalis, and the lateral branches of the anterior rami of the last thoracic and first lumbar (ilio-hypogastric) nerves cross it, one in front of the tubercle and the other behind it. The *tubercle* lies at the most lateral part of the crest, and, therefore, at the highest part visible from the front (*fig. 394*). The *anterior* and *posterior superior spines* cannot be missed. The posterior spine (or rather a flat elevation that lies a little above it and gives attachment to part of the sacro-tuberous ligament) lies at the bottom of a hollow. A line or the edge of a folded towel joining the highest points on the iliac crests crosses the *4th lumbar spine*, and is the guide to it. A line joining the posterior superior spines crosses the *2nd sacral spine* and marks the bottom of the dural and arachnoid sacs with the contained cerebro-spinal fluid. Produced laterally, this line obviously must cross about the *centre of the sacro-*

iliac articulation, because the auricular surface of the ilium articulates with the 1st, 2nd, and 3rd pieces of the sacrum and of these the 2nd is, of course, the middle (*fig. 327*). The top of the *greater (great) trochanter* lies a hand's breadth below the tubercle of the iliac crest (p. 371). A line drawn horizontally at the level of the ischial tuberosity crosses the *lesser trochanter* of the femur, and, as will appear later, indicates the interval between the borders of the Quadratus Femoris and Adductor Magnus. As one

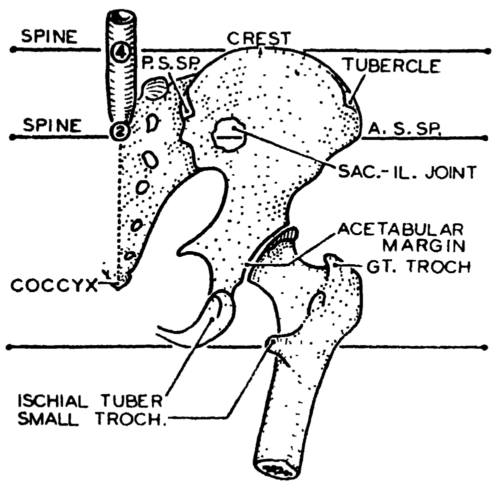


FIG. 394. Bony landmarks of the gluteal region.

does not sit on the lower end of one's vertebral column but on one's ischial tuberosities, it follows that the *coccyx* does not descend so far as the tuberosities. The tip of the coccyx is readily felt in the furrow between the buttocks about $1\frac{1}{2}''$ behind the anus.

The Gluteus Maximus. This very coarse-grained muscle is rhomboidal, that is to say, it is an oblong whose opposite borders are parallel, but whose angles are not right angles (*fig. 395*). It arises from the posterior superior spine and the tip of the coccyx, and from the available bony and ligamentous structures between these two points, namely, the portion of the dorsum ilii between the posterior gluteal line and the iliac crest, the back of the sacro-tuberous ligament [The upper 3 pieces of the sacrum are engaged in the sacro-iliac joint and, so, are not available.] and the back of the lower 2 pieces of the sacrum and the coccyx. When well developed the Gluteus Maximus spreads along the lateral lip of the iliac crest towards the origin of the Ten-

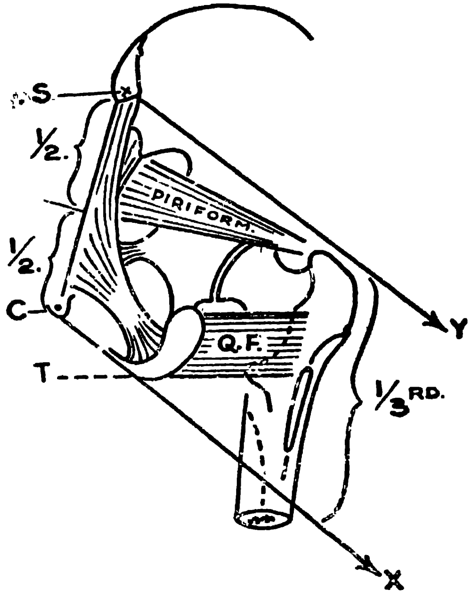


FIG. 395. Outline of Gluteus Maximus. The lower border of the Piriformis is the key line of the gluteal region.

sor Fasciae Latae; and, because there is no more unoccupied bone in the neighbourhood, any further origin must be from adjacent fasciae; for example, the fascia covering the Gluteus Medius and the lumbar (lumbo-dorsal) fascia.

The lower border of the Gluteus Maximus extends from the tip of the coccyx across the ischial tuberosity and onwards to the shaft of the femur, which it reaches at the junction of its upper one-third and lower two-thirds. The tuberosity,

though covered by the Maximus when you stand up, is uncovered when you sit down; i.e., you do not sit on your Gluteus Maximus; fleshy muscle fibers could not survive such abuse. There is a thick mass of stringy fibrous tissue between the tuberosity and the skin on which you rest when sitting, and in it a bursa may be embedded. The upper border of this rhomboidal muscle is, of course, indicated by a line drawn from the posterior superior spine parallel to the lower border. This line passes about one inch above the greater trochanter.

The deep fascia covering the Gluteus Maximus is weak, as is deep fascia covering flat muscles in general, e.g., Pectoralis Major and Trapezius.

One quarter of the Gluteus Maximus—the deep portion of the lower half—is inserted into the gluteal tuberosity of the femur, whereas three quarters end in a bandlike aponeurosis which meets and joins a similar bandlike aponeurosis of the Tensor Fasciae Latae, distal to the greater trochanter, to form the **ilio-tibial** tract or *band*. Now, the ilio-tibial tract descends between the circularly disposed layers of the fascia lata to be attached to the lateral condyle of the tibia well in front of the axis of the knee joint. Vertical fibers of the fascia lata are continued upwards, proximal to the greater trochanter, to be attached to the iliac crest between the anterior superior spine and the tubercle; hence, the qualifying term, *ilio-tibial*, applied to the tract. This upper part of the tract holds the aponeurosis of the Gluteus Maximus in position and it gives origin to the anterior part of the Gluteus Medius.

Owing to the fact that the tract is attached in front of the axis of the knee joint (*fig. 479*), it assists in maintaining the knee joint in the extended position. Of this you can easily satisfy yourself thus:—while sitting down with your limbs extended in front of you, raise your heel off the ground and by palpation note that the anterior border of the ilio-tibial tract, which runs longitudinally a finger's breadth behind the lateral border of the patella, becomes prominent and taut, only to become slack and indistinct again when your heel touches the ground once more.

Many fibers of the Maximus running in the ilio-tibial tract pass into the lateral intermuscular septum and thereby gain attachment to the lateral lip of the linea aspera and to the lateral epicondylar line; hence the fact that the lateral epicondylar line is so much better marked than the medial epicondylar line. Where the Gluteus Maximus plays across the hard, resistant surface of the greater trochanter, its fleshy fibers must, in accordance with general laws, give place to an aponeurosis; and, intervening between this aponeurosis and the trochanter there must be a *bursa* (*fig. 402*). And between the aponeurosis and the fibrous origin of the Vastus Lateralis there is a *second bursa*. The greater trochanter is, therefore, not merely subcutaneous; it is also subaponeurotic.

The Gluteus Maximus is the great extensor of the hip joint. As such, it is brought into action in climbing, walking upstairs, and running; but it is not required in gentle walking. It is also a lateral rotator.

The Door to the Gluteal Region. Before exposing the structures deep to the Gluteus Maximus, you should understand that there is but one door through which all vessels and nerves must pass on leaving the pelvis to enter the gluteal region. The door is the *greater sciatic foramen;* it might well be called the "*Porta*". The Piriformis itself enters by this door. Some vessels and nerves enter the glu-

teal region above the Piriformis; others enter below the Piriformis—but they all enter through the greater sciatic foramen. Some having entered, at once disappear through the lesser sciatic foramen into the perineum—but they made their entry through the greater sciatic foramen. The Obturator Internus is the

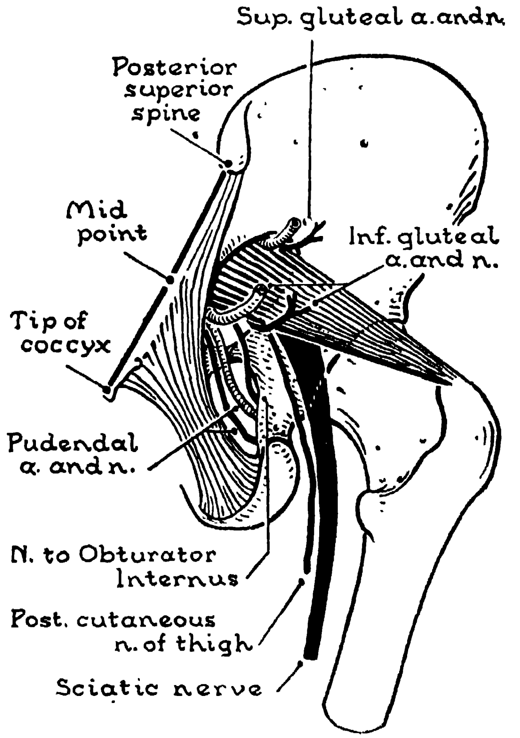


FIG. 396. Structures passing through the "door" to the gluteal region nerve to Quadratus Femoris is hidden by sciatic nerve.

only structure entering by the lesser sciatic foramen. Some of the small vessels taking part in a feeble anastomosis behind the neck of the femur (the cruciate anastomosis) reach the region through or between the muscles of the neighbourhood.

The structures entering *at the lower border of the Piriformis* are, working latero-medially (*fig. 396*):

Sciatic nerve, which hides nerve to Quadratus Femoris.
Inferior gluteal nerve.
Inferior gluteal vessels.
Posterior cutaneous nerve of thigh.
Nerve to Obturator Internus.
Internal pudendal vessels.
(Internal) pudendal nerve.

The lateral 5 of these are in contact with the dorsum ischii. The medial 3 cross the ischial spine or the sacrospinous ligament, pass through the lesser sciatic foramen, and find themselves in the perineum between the Obturator Internus and its fascia. There the nerve to the Obturator Internus enters its muscle; the pudendal vessels and nerve run forwards in the pudendal canal.

The structures entering at the *upper border of the Piriformis* are:

Superior gluteal vessels.
Superior gluteal nerve.

It is, then, apparent that the borders of the Piriformis—and especially its lower border—serve as the guides to these structures. Fortunately, the lower border is easily and accurately indicated on the skin surface by a line joining the midpoint between the posterior superior spine and the tip of the coccyx to the top of the greater trochanter. It is the "*key line*" of the region. Given this line you can easily gauge the position of the upper border of the Piriformis. Separate therefore the fleshy fibers of the Gluteus Maximus or cut through its aponeurosis in this line (*fig. 397*). How will you know when you are through the muscle? (1) The simplest and surest way is to cut boldly right through its aponeurosis and subaponeurotic bursa on to the greater trochanter; then to slacken the muscle by imitating its action, that is by extending and laterally rotating the thigh, so that a finger can be inserted through the

incision and moved circularly. The finger will be deep to the Maximus and to the Maximus only, for the Maximus is the only muscle to cross the trochanter. (2) Alternatively, you may separate the fleshy fibers until the inevitable areolar tissue comes into view—inevitable, because the fleshy fibers of the Maximus are longer than, and take a different direction from, the fibers of the deep muscles. A layer of areolar tissue, perhaps laden with fat, must lie interposed between the Maximus and the

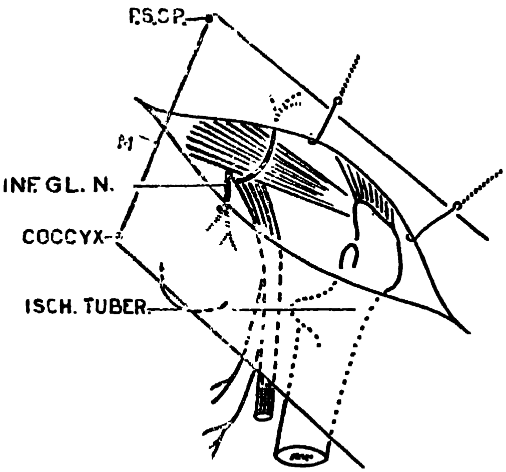


FIG. 397. Incision to be made through the Gluteus Maximus to expose the "key line" of the region.

deeper muscles in order to allow them independent movement.

As the finger is moved about in this plane, it will encounter the NERVE AND VESSELS TO THE MAXIMUS (inferior gluteal nerve and vessels) which enter it at its center. Plunge a probe through the central point of the muscle and verify this. Next identify the **Sciatic Nerve.** It appears from under cover of the lower border of the Piriformis and, curving infero-laterally, descends between the ischial tuberosity and the greater trochanter. Indeed, when the limb is in the anatomical position, i.e., toes pointing forwards, the lateral border of the nerve lies midway between the medial aspect of the tuberosity and lateral aspect of the trochanter. Here the nerve is covered by the Gluteus Maximus, and not until it reaches the lower border of the Maximus does it become subfascial.

Having identified the sciatic nerve and having reflected the lower half of the Maximus, do all preliminary dissecting and cleaning on the lateral side of the nerve, because that is its safe side (*fig. 398*). The sciatic nerve has two sides: a

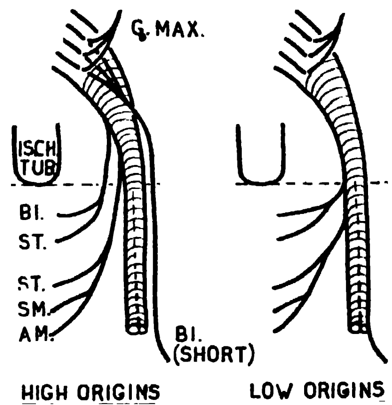


FIG. 398. Principle: Sides of safety and sides of danger.

side of danger and a side of safety. This is due to the double fact (1) that it is the most lateral structure in the region, and (2) that its branches spring from its medial side——because they supply the muscles (the hams) which arise from the ischial tuberosity. Therefore, work on its lateral side: remove fat, clean muscles, and disregard some arterial twigs from the superior and inferior gluteal, medial and lateral femoral circumflex, and first perforating arteries, which describe a cruciate anastomosis (*fig. 412*).

The Great or Greater Trochanter. To find the upper border of the Piriformis

carry the handle of the knife upwards along the posterior free border of the greater trochanter. This will conduct it to the lower border of the Gluteus Medius, which may then be followed medially and upwards towards the greater sciatic notch, where the superficial branches of the superior gluteal vessels appear between adjacent borders of the Medius and Piriformis. Why select the trochanter; why should it be a guide? The tendons of several muscles (G. Medius,

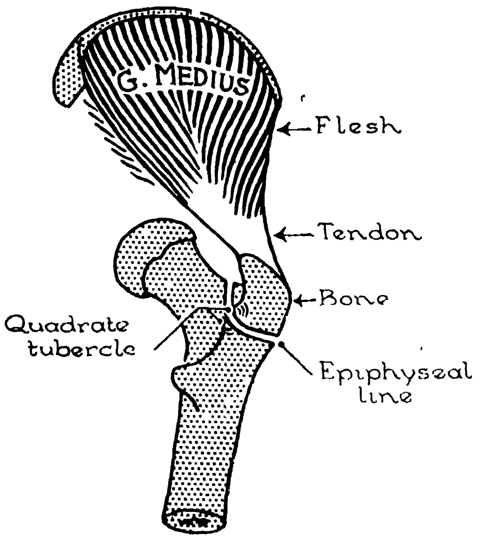


FIG. 399. The fleshy, tendinous, and bony portions of the Gluteus Medius.

G. Minimus, Piriformis, Obturator Internus and its Gemelli, and Obturator Externus) are all inserted into the greater trochanter. Of these the two greatest are (1) the Gluteus Minimus, which is attached to its oblong anterior aspect, and (2) the Gluteus Medius, which is attached diagonally across its lateral aspect from the antero-inferior angle to the postero-superior angle. The postero-superior angle is free and is to be regarded as the ossified part of the tendon of the Medius. The Medius has therefore a fleshy, a tendinous, and an osseous portion (*fig. 399*). The trochanteric crest has the appearance of crystalized fibers. Its upper part is the posterior border of the greater trochanter, and apparently is an extension of the Gluteus Medius. The lower part ascends from the lesser trochanter and is an extension of the Psoas tendon. The two parts are usually discontinuous, and between them there is a rounded eminence, the *quadrate tubercle*, to which the upper fibers of the Quadratus Femoris are attached. The quadrate tubercle is, however, not the creation of the Quadratus, whose insertion is largely fleshy, but corresponds to the epiphyseal line, which passes through it and then follows the rough ridge that separates the greater trochanter from the shaft of the femur both laterally and in front. The aponeurosis of the Vastus Lateralis is in part responsible for this ridge.

The greater trochanter is, then, the traction epiphysis of 5 muscles; of these the Medius is mostly responsible for its shape, causing it to be curved upwards, medially, and backwards and causing it to have a free, posterior border. The tendon of the Piriformis is attached to the middle of the upper border; the tendon of the Obturator Internus and its Gemelli to the front of the upper border; the tendon of the Obturator Externus to a pit on its medial surface; and the tendon of the Minimus, as already mentioned, to the anterior aspect.

The Superior Gluteal Nerve, accompanied by the superior gluteal vessels, passes through the "porta", above the Piriformis, in contact with the margin of the greater sciatic foramen, and it runs with the deep branches of these vessels between the Glutei Medius et Minimus. It supplies the 3 abductors and medial rotators of the hip joint, namely, the Gluteus Medius, Gluteus Minimus, and Tensor Fasciae Latae. These 3 muscles monop-

olize the entire dorsum ilii—save for two small areas: one between the posterior gluteal line and iliac crest where the Gluteus Maximus is attached; the other between the inferior gluteal line and the acetabular margin where the ilio-femoral ligament and the reflected head of the Rectus Femoris are attached.

The Glutei Medius et Minimus. Whereas the Gluteus Maximus is rhomboidal, the Glutei Medius and Minimus are fan-shaped. They are but two parts of a single muscle; they are common in shape, in direction of fibers, in actions, and in nerve supply. Their attachments are contiguous and their anterior borders are commonly fused—or rather, undifferentiated. There is, therefore, no necessity for areolar tissue or fat between them, though a little is commonly present.

It may be noted that the anterior part of the Medius receives many fibers from the overlying fascia (*fig. 400*). Hence, the fascia covering the Medius is thick; whereas that covering the Maximus is thin.

The Tensor Fasciae Latae is about six inches long and on transverse section is apt to be mistaken for the Sartorius, but it is thicker and is $1\frac{1}{4}''$ wide. It arises by a short aponeurosis from the ant. sup. iliac spine and from the adjacent part of the outer lip of the iliac crest. It is directed downwards and slightly backwards. The ilio-tibial tract serves as its tendon of insertion (p. 373).

The Quadratus Femoris may next be defined (*fig. 402*). It is an oblong muscle continuous both at its origin and at its insertion with the Adductor Magnus of which it may be regarded as an upward extension. The division between these two muscles is not always evident. Though both are supplied by the same segments (4, 5, 1), their nerves reach them by different routes. The Quadratus arises from the lateral border of the ischial tuberosity above the impression for the Adductor Magnus. It extends horizontally laterally to the femur, where it is inserted into the quadrate tubercle and into the linear area of bone between this tubercle and the insertion of the Adductor Magnus on the gluteal tuberosity at the level of the lesser trochanter.

Note, the lesser trochanter and the lowest part of the ischial tuberosity are on the same level; as are the quadrate tubercle and the highest part of the ischial tuberosity. In drawing or in picturing relations from the back this con-

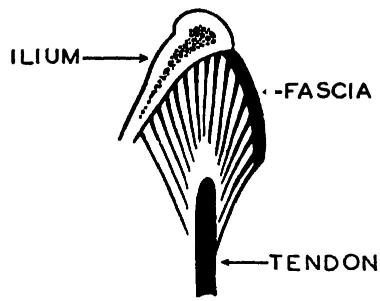


FIG. 400. The Anterior part of the Gluteus Medius arises largely from the fascia covering it; hence, the thickness of this fascia.

sideration should be kept in mind (*fig. 395*).

The nerve to the Quadratus lies between the sciatic nerve and the ischium and is not seen until the sciatic nerve is retracted. In order to allow of this, either the hip must be extended or the knee flexed or both. The nerve to the Quadratus arises from the front of the sciatic nerve, descends in front of the Obturator Internus and its Gemelli, and enters the anterior aspect of the Quadratus. It also supplies a twig to the hip joint and to the Gemellus Inferior.

The Obturator Internus and the Gemelli constitute a tricipital muscle that occupies the interval between the Quadratus and the Piriformis. The *Ob-*

turator Internus arises from almost the entire pelvic surface of the hip bone below the level of the obturator nerve. It takes a right angled turn as it passes through the lesser sciatic foramen (*fig. 330*). From this you will infer that its

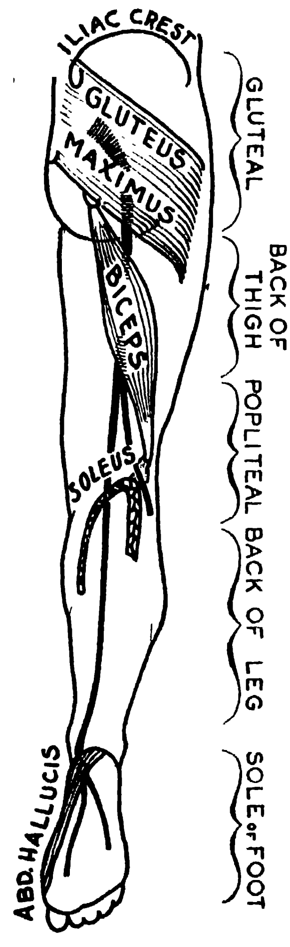


FIG. 401. The five regions of the back of the limb and the four muscles separating them.

anterior surface is here tendinous and that it is separated from the margin of the foramen by a bursa. Its tendon passes across the posterior surface of the ischium and capsule of the hip joint to reach the most anterior facet on the upper border of the greater trochanter. Of the *Gemelli*, the Superior arises from the upper margin of the lesser foramen (ischial spine); the Inferior from the lower margin of the lesser foramen (ischial tuberosity); and their fleshy fibers are inserted into the respective borders and the superficial aspect of the tendon of the Obturator Internus.

The Two Gluteal Arteries, superior and inferior, are responsible for supplying the entire gluteal region, their largest branches being, of course, *muscular*. The superior artery supplies a *nutrient* artery that enters the ilium on the middle gluteal line. The inferior artery sends a branch to the *sciatic nerve*, a branch that follows the nerve to the Quadratus Femoris, and *cutaneous branches* that accompany twigs of the posterior femoral cutaneous nerve down the thigh and around the lower border of the Maximus.

Note the manner in which the superior gluteal vessels hook round the margin of the greater sciatic notch.

The Posterior Cutaneous Nerve of the Thigh is purely sensory. It lies first medial to the sciatic nerve and then behind it, clinging to Gluteus Maximus. Its *gluteal branch* turns round the lower border of the Maximus. Its *perineal branch* passes lateral to the ischial tuberosity and enters the pouch of Colles to supply the scrotum or labium majus (*fig. 313*), while the main nerve continues down the middle of the thigh subfascially to end on the calf (p. 405).

The Five Regions of the Back of the Limb. The back of the lower limb is divided for descriptive purposes into five regions (*fig. 401*):

1. The Gluteal Region.
2. The Back of the Thigh.
3. The Popliteal Fossa.
4. The Back of the Leg.
5. The Sole of the Foot.

The iliac crest limits the gluteal region

above; the lower border of the Gluteus Maximus separates it from the back of the thigh; the lower border of the long head of the Biceps (beyond the point at which it crosses the Semimembranosus) separates the back of the thigh from the popliteal fossa; the upper border of the Soleus separates the popliteal fossa from the back of the leg; and the back of the leg becomes the sole of the foot at the upper border of the Abductor Hallucis.

Now, passing deep to all four of these muscles—Gluteus Maximus, Biceps (long head), Soleus, Abductor Hallucis—is the tibial division of the sciatic nerve.

THE BACK OF THE THIGH AND THE POPLITEAL FOSSA

The Deep Fascia (fascia = a bandage) of these regions is composed of circularly arranged fibers, which, though not dense, are very strong, especially behind the knee where to the hamstrings they play the part of a restraining or retinacular ligament, such as occurs at the wrist and ankle. It follows that a transverse incision made through the deep fascia will close of its own accord and that a longitudinal one will tend to gape.

The Floor. The back of the thigh and the popliteal fossa have a flat anterior aspect or floor (*fig. 402*). *The Floor of the Back of the Thigh* has 2 parts: (a) a part medial to the linea aspera formed by the Adductor Magnus, which is covered by the thin posterior intermuscular septum; and (b) a part lateral to the linea aspera formed by the Vastus Lateralis, which is covered by the strong lateral intermuscular septum. The lateral septum is stronger than either the medial or the posterior septum for reasons given (p. 395).

The Floor of the Popliteal Fossa is formed from above downwards by: the popliteal surface of the femur, the posterior part of the capsule of the knee joint, and the Popliteus fascia (fascia covering the Popliteus). Of these, the popliteal surface of the femur is limited below by the intercondylar line; the fibres

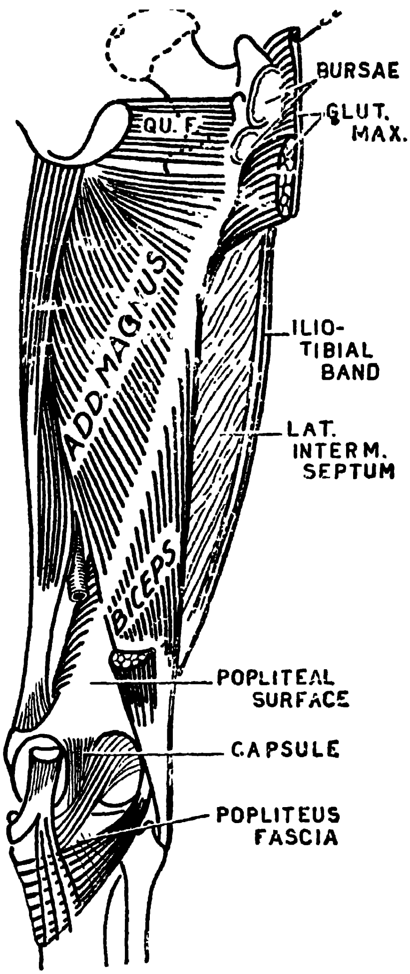


FIG. 402. The "floor" of the back of the thigh and popliteal fossa.

of the posterior part of the fibrous capsule (oblique lig.) are parallel to the Popliteus and, so, tend to save it from being overstretched; the Popliteus fascia is thin laterally, but it is strong medially and its fibers take a vertical course because

they are the media through which the Semimembranosus gains attachment to the soleal line on the tibia.

Contents of the Back of the Thigh:

1. The hamstring muscles.
2. The short head of the Biceps Femoris.
3. The sciatic nerve.
4. Certain vessels.

The Hamstring Muscles. A hamstring muscle may be defined as one that (a) arises from the ischial tuberosity,

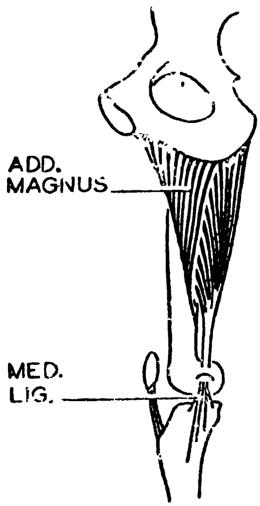


FIG. 403. The ischial part of the Adductor Magnus + the medial ligament of the knee fulfil the requirements of a hamstring muscle.

(b) is inserted into one or other of the two bones of the leg, and (c) is supplied by the tibial (or medial) division of the sciatic nerve. The hamstring muscles, therefore, span the femur but gain no attachment to it. They extend the hip joint and flex the knee joint; and, on this account, you cannot extend your knee fully while your hip is fully flexed.

The hamstrings are 3 in number: the long head of the Biceps Femoris, the Semitendinosus, and the Semimembranosus. Embryologically, the portion of the Adductor Magnus arising from the ischial tuberosity is to be grouped with the hamstrings, thus forming a fourth, the reasons being: (1) it arises from the tuberosity, (2) it is supplied by the tibial division of the sciatic nerve, and (3) its original insertion was into the tibia via the medial (tibial collateral) ligament of the knee (*fig. 403*). Thus, it fulfils the three requirements of a hamstring. On this basis of classification, as you will see, the short head of the Biceps cannot be counted with the hamstrings.

When the knee is flexed, the Biceps, being attached to the head of the fibula, rotates the leg laterally; the Semimembranosus and Semitendinosus, being attached to the medial side of the tibia, rotate the leg medially.

INSERTIONS. *The Biceps* is inserted by tendon into the head of the fibula just in front of the styloid process. It covers the attachment of the lateral ligament of the knee, a bursa intervening, and it partly blends with the deep fascia on the front of the leg (*fig. 425*). *The Semitendinosus* is inserted by aponeurosis into the medial surface of the tibia deep to the Sartorius and Gracilis (*fig. 417*). It is also extensively attached to the deep fascia of the leg. *The Semimembranosus* is inserted by a very thick tendon into the horizontal groove on the medial condyle of the tibia, deep to the medial ligament of the knee, a bursa intervening; by the Popliteus fascia into the soleal line; and by tendon into the posterior surface of the tibia above the Popliteus (*fig. 435*). *The Adductor Magnus* is attached to the tibia, but only indirectly via the medial ligament of the knee (*fig. 403*).

THE ISCHIAL TUBEROSITY is of much smaller surface area than a transverse section of the fleshy bellies of the ham muscles that spring from it; so, it follows that their origins must be fibrous. On

this account a traction epiphysis might reasonably be expected; and an epiphysis there is.

The precise origins of the hamstrings from the ischial tuberosity, though not important, are shown in figure 404. The medial curved border of the tuberosity gives attachment to the sacrotuberous ligament and is therefore sharp; the lateral border gives attachment to the fleshy fibers of the Quadratus Femoris and is therefore smooth. The sacrotuberous ligament is regarded as the divorced tendon of the long head of the Biceps, which is assumed to have arisen originally from the sides of the sacrum and coccyx. The Biceps arises from a medial impression on the tuberosity adjacent to the sacrotuberous ligament with which some of its superficial fibers are continuous. With a little care the "common tendon" of the Biceps and Semitendinosus may be separated into two, right up to the tuberosity. [The technical term "common tendon" merely implies close coaptation of two or more tendons—so close that the point of the scalpel may be required to separate them.] By exclusion, the Semimembranosus arises from a lateral (and upper) impression. The Semimembranosus is membranous in its upper half, fleshy in its lower half, while the Semitendinosus conversely is fleshy in its upper half and tendinous in its lower half; so, though the Semitendinosus lies superficial to the Semimembranosus the one does not interfere with the action of the other. The membrane of origin of the Semimembranosus resembles the blade of a hollow ground razor. Into it the rounded fleshy belly of the Semitendinosus fits. Of necessity, the Semimembranosus and the long head of the Biceps cross each other to reach their respective insertions. The impression for the hamstring portion of the Adductor Magnus occupies the lower and lateral part of the tuberosity and is continuous with the site of attachment of the obturator part.

The Short Head of the Biceps Femoris is not a hamstring. It belongs to the same muscle sheet as the Gluteus Maximus. It is supplied by a branch of the lateral or peroneal division of the sciatic nerve. If you dissect this branch upwards, you will find that it arises from the back of the sacral plexus in common with the nerve to the Maximus (*fig. 398*). The short head arises by fleshy fibers

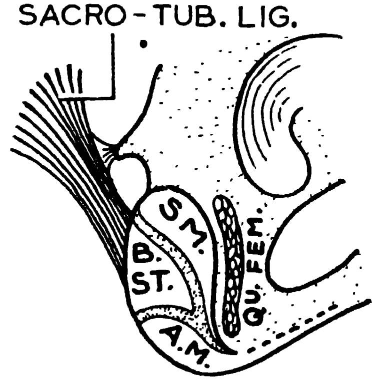


FIG. 404. The ischial tuberosity and the structures attached to it.

from the lateral lip of the linea aspera and from the upper part of the lateral epicondylar line and adjacent part of the lateral intermuscular septum. Its upper limit reaches to the insertion of the Gluteus Maximus (*figs. 402, 412*). How far down the epicondylar line the Biceps extends may easily be calculated from the 3 following considerations:

1. A muscle fiber on contracting shortens by approximately a third of its length.

2. Fleshy fibers never play across resistant structures, such as bone or ligament, which would imperil their vitality, but always give place to fibrous tissue.

3. By palpation of your own knee, you may determine that the head of your

fibula (the site of insertion of the Biceps) makes an excursion of about 1½ inches when the knee joint flexes and extends.

Therefore, the fleshy fibers of the short head require to be approximately 4½ inches long. The muscle must, however, be tendinous from the point at which it crosses and rubs against the lateral (fibular collateral) ligament of the knee, say its last inch; so, its lowest attachment to the femur cannot be nearer the fibular head than 5½ inches. Not uncommonly the Biceps does descend lower on the femur, but in these instances it leaves the epicondylar line and creeps medially across the popliteal surface, thereby maintaining fibers of requisite length. A *bursa* is, according to rule, interposed between the Biceps tendon and the lateral ligament of the knee.

Hybrid or Composite Muscles. The Biceps clearly is an amalgamation of two muscles. The long head, supplied by the tibial division (see below) of the sciatic nerve, belongs developmentally to the front of the limb; the short head, supplied by the peroneal division, belongs to the morphological back. The Adductor Magnus also is an amalgamation of two primitively distinct elements, supplied by the obturator nerve and the tibial division of the sciatic nerve respectively, so both belong developmentally to the front of the limb. (See Pectineus, p. 382.)

The Sciatic Nerve is readily accessible deep in the angle between the Gluteus Maximus and the long head of the Biceps, because it is there subfascial (*fig. 401*). By the sense of touch hook a finger round it and bring it to the surface. Make sure you have not hooked up the Semimembranosus by mistake, as is easily done, for the nerve runs along the lateral side of the Semimembranosus. The nerve is dull; the tendon is glistening. Above the angle the Maximus covers the nerve; below the angle the Biceps covers it; and deep to the Biceps the nerve separates into its two terminal divisions: *tibial* and *peroneal,* known as the *medial* and *lateral popliteal nerves* respectively. The two divisions are merely bound together by loose areolar tissue and may be separated from each other right up to the sacral plexus. In fact, the peroneal division of the sciatic nerve sometimes pierces the Piriformis instead of passing below it with the tibial division (*fig. 405*). The peroneal division and the femoral and gluteal nerves supply the morphological back of the limb; the tibial division and the obturator nerve supply the morphological front, as a consideration of their ultimate distributions to the sole and dorsum of the foot will suggest. The sciatic nerve runs midway between the ischial tuberosity and the greater trochanter, and it is at once reasonable and correct to suppose that the branches it supplies to the hamstrings spring from its ischial or medial side (*fig. 398*).

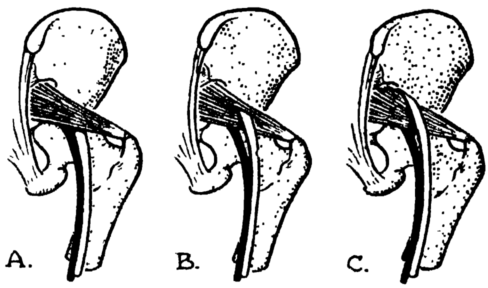


FIG. 405. The relationship of the sciatic nerve to the Piriformis: (a) in 87.5% of 420 limbs both the tibial and the peroneal division of the sciatic nerve passed below the Piriformis; (b) in 12% the peroneal division passed through the Piriformis; and (c) in 0.5% (i.e., in both limbs of one subject) it passed above.

AXIOM. The side from which a motor nerve leaves its parent stem is constant—it leaves from the side nearest the muscle it supplies—but the level at which it leaves is variable; it may arise high or it

may arise low. Nerve trunks, therefore, have *sides of danger and sides of safety* or of relative safety; a side on which it is safe to dissect or operate and a side on which work must be done with caution. In dealing with nerve trunks think vertically not horizontally. This principle is particularly applicable to the sciatic and medial popliteal nerves in the lower limb and to the median and radial nerves at the elbow.

The nerve to the short head of the Biceps springs from the lateral side of the sciatic nerve (peroneal division).

ANTERIOR RELATIONS. The immediate anterior relations of the sciatic nerve throughout its course are: the dorsum ischii (half an inch), Obturator Internus and Gemelli, Quadratus Femoris, and Adductor Magnus. It is separated from the hip joint by the Inferior Gemellus and upper part of the Quadratus Femoris.

The Posterior Cutaneous Nerve of the Thigh. The dividing line between the morphological anterior and posterior cutaneous areas of the thigh is indicated posteriorly by the *posterior cutaneous nerve.* As evidence of this, note that in cases where the sciatic nerve is divided by the Piriformis into peroneal and tibial divisions, the posterior cutaneous nerve derives a root from each. The posterior cutaneous nerve travels down the middle of the back of the thigh immediately under the deep fascia (the long head of the Biceps alone intervening between it and the sciatic nerve) and gives cutaneous twigs to right and to left, but it is not until it reaches the popliteal fossa that the main stem outcrops on the surface to end on the calf.

Arteries. The arteries to the back of the thigh see pp. 411–413.

The Popliteal Fossa or Back of the Knee. The anterior wall or floor of the fossa is described on page 401 (*fig. 402*). The fossa is a potential one before dissection is undertaken. This is owing to the circular arrangement of the fibers in the deep fascia that bandage the structures together. The fossa is composed of an upper and a lower triangle, one being above the knee joint; the other below it. The sides of the upper triangle are: *medially,* the Semimembranosus overlaid by the Semitendinosus; *laterally,* the short head of the Biceps overlaid by and fused with the long head. These embrace the sides of the lower triangle,

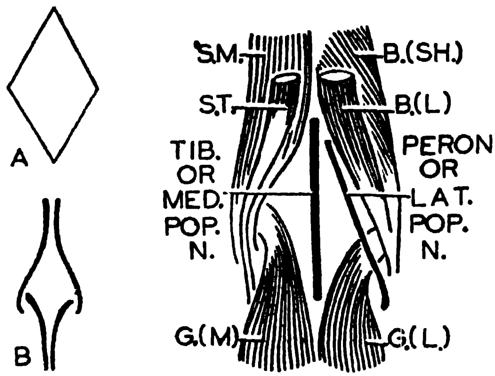


FIG. 406. The boundaries and subdivisions of the popliteal fossa.

formed by the two heads of the Gastrocnemius, together with the unimportant and variable Plantaris which lies laterally. (*Fig. 406.*)

PALPABLE TENDONS. While sitting down—one knee being bent to a right angle or less and the fingers of each hand passed behind the respective sides of this knee—intermittently press the heel backwards against the leg of the chair, noting that: (a) laterally, the *Biceps tendon,* which is here the most dorsal structure, becomes taut and is easily followed to the head of the fibula; do not mistake it for the prominent posterior border of the *ilio-tibial tract* which runs a full finger's breadth in front of it; (b) medially, the

Semitendinosus tendon is felt to spring, like a bow-string, backwards from the lateral edge of the Semimembranosus, and the *Gracilis tendon* is felt, though it is not always distinguished from the medial edge of the *Semimembranosus* behind which it runs (*fig. 482*). Further, the Biceps tendon becomes taut on lateral rotation of the leg (the knee being flexed); the Gracilis tendon becomes taut on medial rotation against resistance (e.g., the big toe pressed against the opposite ankle, the heel being off the floor) and is now readily distinguishable from the Semimembranosus.

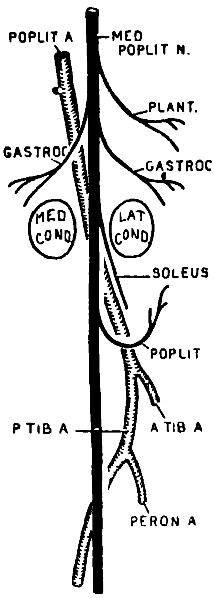


FIG. 407. The medial popliteal nerve: Its side of safety and side of danger and its relation to the bowed arterial stem.

CONTENTS. The fossa contains four important structures:

(1) the medial popliteal nerve.

(2 and 3) the popliteal artery and vein.

(4) the lateral popliteal nerve.

The Medial Popliteal Nerve. The tibial division of the sciatic nerve, known in this region as the medial popliteal nerve, passes from the upper to the lower angle of the diamond-shaped frame, bisecting it longitudinally. It supplies the local muscles, namely, the Plantaris, medial and lateral heads of the Gastrocnemius, Soleus, and Popliteus. Of these 5 muscles only one, the medial head of the Gastrocnemius, lies medial to the medial popliteal nerve, the other four lie lateral. On this account it is safer to work on the medial side of the fossa where only one nerve is in peril. Having identified the nerve to the medial head, it is safe to retract the medial popliteal nerve laterally and to expose the popliteal vessels (*fig. 407*). To obtain ample access to the fossa, the knee should be bent and the heads of the Gastrocnemius separated widely with the fingers and raised freely from the underlying structures.

Relationships. The relative positions of the popliteal artery, popliteal vein, and medial popliteal nerve may to some extent be surmised from the following: (a) The femoral vessels pass down the front of the thigh to become the popliteal vessels at the hiatus in the Adductor Magnus. The sciatic nerve passes down the back of the thigh, and its medial popliteal branch meets the popliteal vessels and continues on a posterior plane. (b) The femoral vein, which was seen to lie behind its artery at the apex of the femoral triangle, retains its posterior relationship in the popliteal fossa. (c) The vessels enter the popliteal fossa from the medial side and, therefore, are at first medial to the nerve, which enters at the upper angle and bisects the space. (d) As the medial popliteal nerve and the popliteal vessels are passing through the narrow ravine bounded on each side by a femoral condyle and a head of the Gastrocnemius, they are crowded one behind the other; the order from the surface to the floor

of the fossa being retained—nerve, vein, artery. The customary order—nerve, artery, vein—does not hold here. (c) Thereafter, the vein and nerve cross the artery very gradually from lateral to medial side; or rather it is the artery that crosses the vein and nerve, for it inclines laterally towards the neck of the fibula, but before reaching the neck it divides into anterior and posterior tibial arteries. The anterior tibial artery continues to the neck; the posterior tibial artery bends medially.

The Popliteal Artery divides into its two terminal branches at the upper border of the Soleus or, which amounts to the same thing, at the lower border of the Popliteus. The arteries below the knee are accompanied by venae comites; so, the *popliteal vein* begins as an assembly of veins. The popliteal artery and vein are just as inseparably bound together in a fascial tube as are the femoral artery and vein—neither can move without the other, and a dilated artery will tend to obstruct the vein.

In front of the popliteal artery is the floor of the fossa. At the hiatus in the Adductor Magnus the Vastus Medialis generally keeps the artery from touching the femur. Where the artery bridges the fossa, betwen the hiatus and the intercondylar notch, it is separated from the bone by fat (*fig. 408*).

THE BRANCHES of the popliteal artery are: cutaneous, muscular to the muscles of the back of the thigh and of the calf, and articular (*p. 413 and fig. 412*).

The Lateral Popliteal Nerve separates from the sciatic nerve about the middle of the thigh and ends lateral to the neck of the fibula by dividing into three terminal branches—*anterior tibial, musculocutaneous* and *anterior tibial recurrent.* It appears from under cover of the long head of the Biceps and follows the Biceps tendon. As, however, the Biceps is inserted into the head of the fibula and the nerve winds behind the head and round the neck of the fibula, it follows that the nerve recedes gradually from the tendon, crossing in turn: the Plantaris, Gastrocnemius (lateral head), and the back of the head of the fibula where a thin fleshy veneer of Soleus partly separates it from the head. Hence, it is readily palpated behind the head where it is felt to slip from under the finger-tips drawn horizontally across it (cf. the ulnar nerve behind the medial epicondyle).

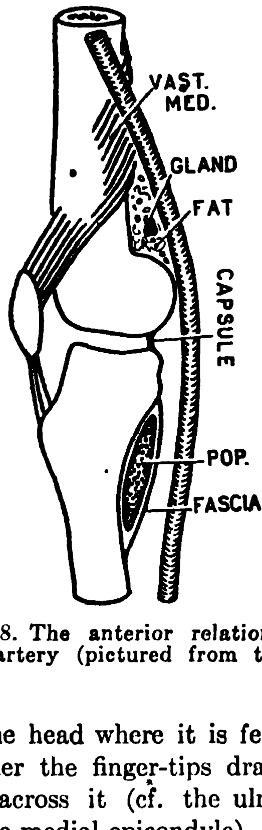


FIG. 408. The anterior relations of the popliteal artery (pictured from the medial side).

BRANCHES: (A) Terminal (*fig. 425 & p. 419*). (B) Collateral: (a) there are no motor branches; (b) the sensory branches are:

Articular and *cutaneous branches* spring from both popliteal nerves. The medial popliteal nerve supplies 3 articular or genicular branches (the supero-medial, infero-medial, and the middle); the lateral

popliteal nerve supplies 2, (the supero-lateral and infero-lateral). They accompany the corresponding vessels. The cutaneous branch of the medial popliteal nerve, called the *sural nerve*, lies with the short saphenous vein in the furrow between the two bellies of the Gastrocnemius. It is joined by the cutaneous branch of the lateral popliteal nerve (called the *communicating sural nerve*) which travels distally on the lateral head of the Gastrocnemius.

The Short Saphenous Vein begins in the dorsal venous arch of the foot. It passes below and then behind the lateral malleolus and is accompanied in its course by the sural nerve. It pierces the popliteal fascia and, after dividing, ends in the popliteal and profunda femoris veins.

A large cutaneous branch, the *medial femoral cutaneous vein*, connects it to the upper end of the long saphenous vein.

Lymph Glands. The most distal glands in the limb are small glands beside the anterior and posterior tibial vessels. They intercept deep lymph vessels, drain into the popliteal glands, and have little practical value. Five or six small *popliteal glands* lie in the fat around the popliteal vessels. They receive the distant deep lymph vessels and vessels from the knee joint; and they drain into the deep inguinal glands by vessels that follow the femoral vessels. One gland lies just under the deep fascia beside the short saphenous vein. It drains the same territory as the short saphenous vein, and it is the lowest gland in the limb draining superficial tissues. Its efferent vessels also follow the femoral vessels. The corresponding gland in the upper limb, the *supratrochlear gland*, lies superficial to the deep fascia.

THE MEDIAL REGION OF THE THIGH

Muscles. The muscles of the medial or adductor region of the thigh arise collectively from the anterior aspect of the hip bone between ilio-pubic eminence above and the ischial tuberosity below (including the superior ramus, body, and inferior ramus of the pubis; the ramus and tuberosity of the ischium, and the obturator membrane) (*fig. 409*). From this compact area of origin they spread out fanwise to a linear insertion, that extends from the trochanteric fossa of the femur above to the upper part of the medial surface of the tibia below (*fig. 410*). Their chief actions are those of adduction and lateral rotation of the hip joint. The obturator nerve innervates them. The profunda femoris and obturator arteries nourish them. They form a much larger mass than the Coracobrachialis, which is their homologue in the upper limb.

The muscle mass consists of six individual muscles:

Origins The *Pectineus*, *Adductor Longus*, and *Gracilis* have a continuous curvilinear origin that extends from the ilio-pubic eminence to the (inferior) ramus of the ischium. The origin of the Pectineus, which is fleshy, meets that of the Adductor Longus, which is tendinous, at the pubic tubercle; the Gracilis has an aponeurotic origin. If the thigh be abducted, the tendon of the Longus becomes prominent and palpable and acts as a guide to the pubic tubercle. The *Adductor Brevis*, *Adductor Magnus*, and *Obturator Externus* arise by fleshy fibers in successively deeper, overlapping planes.

Insertions. The restricted and therefore fibrous insertions of these 6 muscles are as follows: The *Pectineus:* to the line

running from lesser trochanter towards the linea aspera. The *Adductor Longus:* to almost the whole length of the linea aspera in line with the Pectineus. (Between the Pectineus and Longus the Brevis can be seen.) The *Gracilis:* to the medial surface of the tibia below the level of the tuberosity and between the insertions of the Sartorius and Semitendinosus. The Gracilis is the only muscle of the adductor group to cross the knee joint. (Between the Longus and Gracilis the Magnus can be seen) (*fig. 389*). The *Adductor Brevis:* to the lower part of the pectineal line and upper part of the linea aspera. Its upper part is overlapped by the Pectineus; its lower part by the Adductor Longus. The *Adductor Magnus:* to the linea aspera, extending upwards on to its lateral continuation (the gluteal tuberosity), and downwards on to its medial continuation (the medial epicondylar line). In fact, it extends from the level of the lesser trochanter above, where it is continuous with the Quadratus Femoris, to the adductor tubercle below. The portion of the Adductor Magnus that arises from the ischial tuberosity is tendinous, is supplied by the tibial division of the sciatic nerve, and belongs developmentally to the hamstring muscles. The tendinous cord passing to the adductor tubercle and to the epicondylar line just above it belongs to the sciatic portion. The *Obturator Externus:* to the trochanteric fossa. It passes below the head of the femur and grooves the back of the neck. It will be studied with the hip joint.

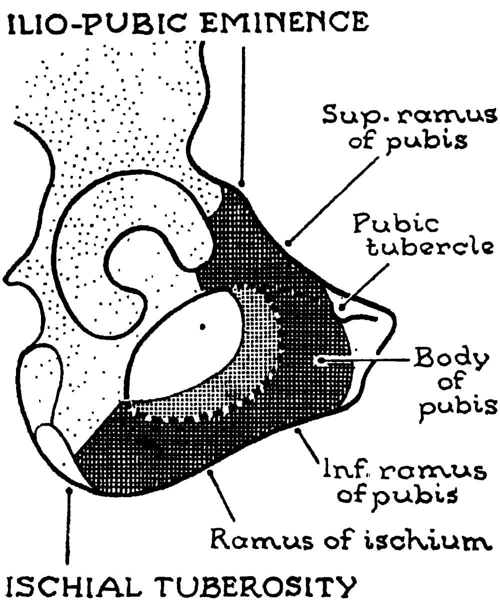


FIG. 409. The compact area of origin of the Adductors.

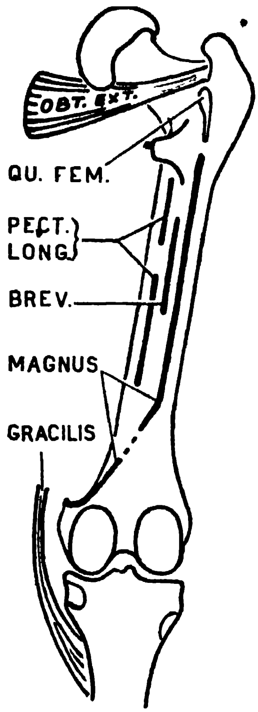


FIG. 410. The linear insertion of the Adductors extends from the trochanteric fossa above to the medial surface of the tibia below.

If you would be familiar with the shaft of the femur, and the relations of the

profunda artery and of the obturator nerve, you must spend some minutes in defining the insertions of these muscles.

Three Hernial Sites. (a) that the Pectineus and the superior ramus of the pubis would separate a femoral hernia from an obturator hernia; (b) that the inguinal ligament would separate a femoral hernia from an inguinal hernia (*fig. 411*).

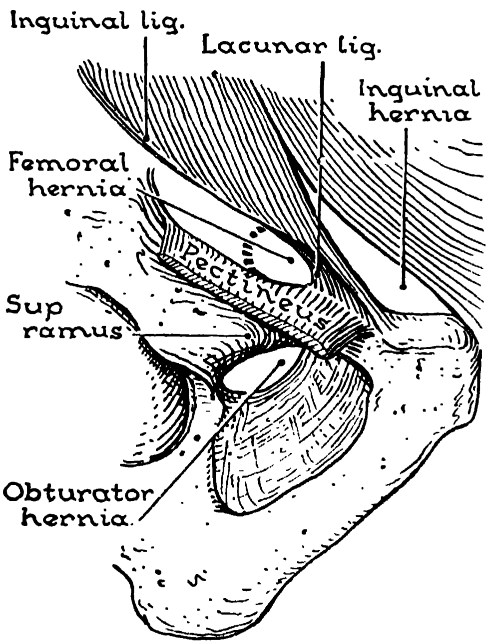


FIG. 411. Three hernial sites

The Obturator Nerve (*fig. 463*), like the femoral nerve, is derived from the anterior rami of the 2nd, 3rd, and 4th lumbar nerves, and like it, has a motor, a cutaneous, an articular, and a vascular distribution.

On passing through the obturator foramen the nerve divides into an anterior and a posterior division. The anterior division passes over the upper border of the Obturator Externus and descends in front of the Adductor Brevis to supply (Pectineus sometimes), Longus, Brevis, and Gracilis. The posterior division pierces the upper border of the Obturator Externus, descends behind the Brevis, and supplies the Obturator Externus and the Magnus.

To display the *anterior* division, the Pectineus and the Adductor Longus need be reflected; to display the *posterior* division, the Adductor Brevis also must be reflected (*fig. 413*).

Hybrid Muscles. The Pectineus and Adductor Magnus are composite or "hybrid" muscles with double nerve supplies. The femoral nerve supplies the lateral part of the Pectineus and often the entire muscle; the obturator or the accessory obturator nerve sometimes supplies the medial part. The obturator nerve supplies the part of the Adductor Magnus that arises from the pubic arch; the tibial division of the sciatic nerve supplies the part that arises from the ischial tuberosity. Functionally, both muscles must be grouped with the adductors of the hip joint. Developmentally, however, the Pectineus belongs, in part at least, to the Ilio-psoas or flexor mass; the Magnus to the hamstring or extensor mass. The obturator nerve has, therefore, the assistance of the femoral and sciatic nerves in supplying the marginal parts of the adductor muscle mass.

OTHER BRANCHES OF THE OBTURATOR NERVE. The sole *cutaneous branch* is a continuation of the nerve to the Gracilis. It reaches the surface about the middle of the thigh, where it supplies a restricted area. It may, however, extend to the calf. *Articular branches* supply the hip joint and commonly the knee. The one passes through the acetabular notch to the hip joint; the other is a continuation of the nerve to the Adductor Magnus. The latter pierces this muscle above the hiatus for the femoral vessels, runs down on the medial side of the popliteal vessels,

and pierces the posterior part of the capsule of the knee. *A vascular branch* passes to the femoral artery.

An Abnormal Branch. Both the femoral and the obturator nerves are derived from the anterior rami of lumbar nerves 2, 3, and 4. In embryonic life, while the developing superior ramus of the pubic bone, as yet in a condensed cellular state, is growing medially to meet its fellow at the symphysis, it insinuates itself between the femoral and obturator nerves and separates them. Commonly this sprouting ramus penetrates the obturator nerve with the result that a detached strand, the *accessory obturator nerve*, follows the medial border of the Psoas over the superior ramus and rejoins the main nerve deep to the Pectineus. It may supply a twig to the hip joint and to the Pectineus.

Note: (a) that the femoral and profunda femoris arteries are separated by the Adductor Longus, and (b) that the anterior and posterior divisions of the obturator nerve are separated by the Adductor Brevis (*figs. 412, 413*).

The Obturator Artery assists the profunda artery to supply the adductors. Arising either from the internal iliac artery or as "an abnormal obturator" from the inferior epigastric artery, it traverses the obturator canal, enters the thigh, and divides into anterior and posterior branches which skirt the circumference of the obturator foramen. The posterior branch and the medial femoral circumflex a. each send an *articular* twig through the acetabular foramen to the acetabular fossa. There they ramify in the Haversian pad of fat, and one or other traverses the lig. of the head of the femur (lig. teres, *fig 468*) and helps to nourish the head.

Arteries. By their anastomoses the arteries to be described maintain rather indifferently the circulation in the limb after the femoral artery has been obstructed. A detailed knowledge of their courses implies a knowledge of the femur and of the muscles attached to it. So, only if you have traced the muscles to

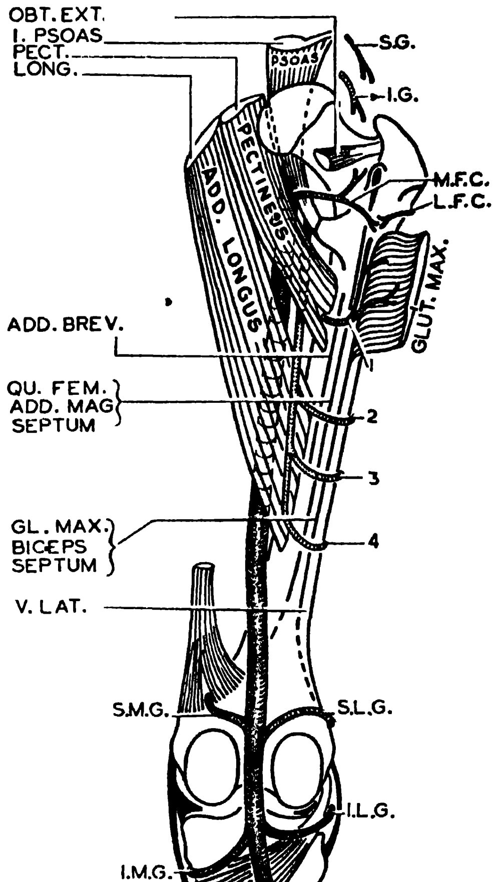


Fig. 412. The great arteries. Observe their branches closely embracing the bones.

their attachments on the femur can you appreciate the following description. It would be foolish to commit the courses to memory.

The Profunda Femoris Artery is nearly as large as the continuation of the femoral artery. It arises from the lateral

side of the femoral artery about 1½ inches below the inguinal lig. At the apex of the femoral triangle it lies behind the femoral vessels and its own vein. It passes through the gap between the insertions of the Pectineus and Adductor Longus and descends first between the Longus and Brevis, then between the Longus and Magnus, and ends as the 4th perforating artery. Lying closer to the bone than the femoral artery, it crosses in turn the Iliacus, Pectineus, Adductor Brevis, and Adductor Magnus (*figs. 412, 413*).

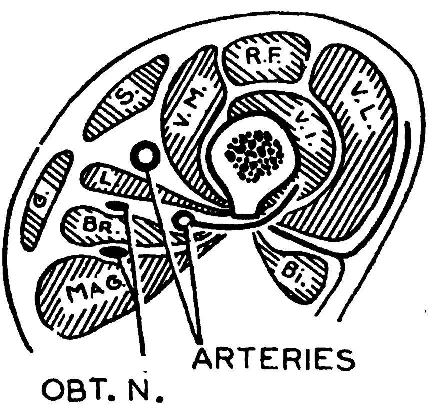


FIG. 413. Cross section of thigh. (A) The Longus separates the femoral and profunda femoris arteries. (B) The Brevis separates the divisions of the obturator nerve. (C) The perforating arteries hug the bone.

Distribution. Its various branches supply most of the muscles of the thigh; articular branches pass to the hip and knee joints; and medullary branches pass to the femur, and numerous anastomoses are effected. The branches are:

a. Lateral femoral circumflex.
b. Medial femoral circumflex.
c. Muscular.
d. First
e. Second
f. Third
g. Fourth } perforating.

THE LATERAL FEMORAL CIRCUMFLEX A. is a large artery which runs laterally between the branches of the femoral nerve, deep to the Sartorius and Rectus Femoris, and divides into three branches. The *ascending* and *transverse* branches anastomose in the gluteal region and they send branches along the neck of the femur to supply it. The *descending* branch follows the anterior border of the Vastus Lateralis and anastomoses at the knee.

THE MEDIAL FEMORAL CIRCUMFLEX A., *the four perforating aa., and the termination of the femoral a.* are in series, as they wind backwards round the medial side of the femur, hugging it closely, and either passing between the borders of muscles or disturbing their attachments to the bone. The medial femoral circumflex a. may be regarded as a perforating artery that clings to the bone in the later part of its course. Having passed first between Psoas and Pectineus, then between Obturator Externus and Adductor Brevis, it abuts against the Quadratus Femoris and there divides into (1) a transverse branch that passes onwards between the borders of the Quadratus and Adductor Magnus to anastomose with the transverse branch of the lateral femoral circumflex, and (2) an ascending branch that passes upwards deep to the Quadratus to anastomose with the inferior gluteal artery behind the neck of the femur. An articular branch passes from the medial circumflex a. through the acetabular foramen to the hip joint.

THE 4 PERFORATING AA. encircle the shaft of the femur, interrupting the attachment of each muscle they encounter thus: The 1st interrupts the Adductor Brevis and Magnus and ends in the Gluteus Maximus; the 2nd interrupts the Adductor Brevis and then, like the 3rd and 4th, it interrupts the Adductor Magnus, short head of the Biceps, lateral intermuscular septum, Vastus Lateralis and ends in the

Vastus Intermedius. The medullary artery of the femur is derived from the 2nd or 3rd perforating artery. The femoral a. passes between the obturator and sciatic parts of the Adductor Magnus.

Anastomoses. The term *cruciate anastomosis* is applied to the union of the medial and lateral femoral circumflex arteries with the inferior gluteal artery above and the 1st perforating artery below. At the back of the limb the perforating arteries form a feeble arterial chain that links the cruciate anastomosis at the hip to the genicular anastomosis at the knee.

The Branches of the Popliteal Artery are: a few *cutaneous* branches; *muscular* branches to the muscles of the ham and calf; and *5 genicular* (articular) branches. Of these the middle genicular pierces the capsule of the knee joint and supplies the cruciate ligaments and other derivatives of the intercondylar septum (*fig. 484*). The other 4, like the perforating branches of the profunda a., grasp the skeletal framework, no muscle intervening.

Development of the Arteries. In the embryo the primary arterial trunk of the limb arises as a branch of the internal iliac a., and passes down the back of the limb, accompanying the sciatic nerve; at the knee it passes in front of the Popliteus; and in the leg it lies behind the interosseous membrane. A vessel, which becomes the external iliac and femoral arteries, grows down the front of the thigh and joins the primary trunk at the knee (*fig. 414*). The part of the primary trunk immediately distal to the union becomes the upper part of the popliteal artery; the proximal part is resorbed, save in the gluteal region where it persists as the inferior gluteal artery. Anastomotic branches—medial femoral circumflex and 4 perforating—also connect the two trunks. The primary trunk sends a branch forwards between the leg bones to become the anterior tibial artery; and a branch (or branches) downwards behind the Popliteus to become the lower part of the popliteal artery and the posterior tibial artery. Thus, the Popliteus is encircled temporarily—until the portion of

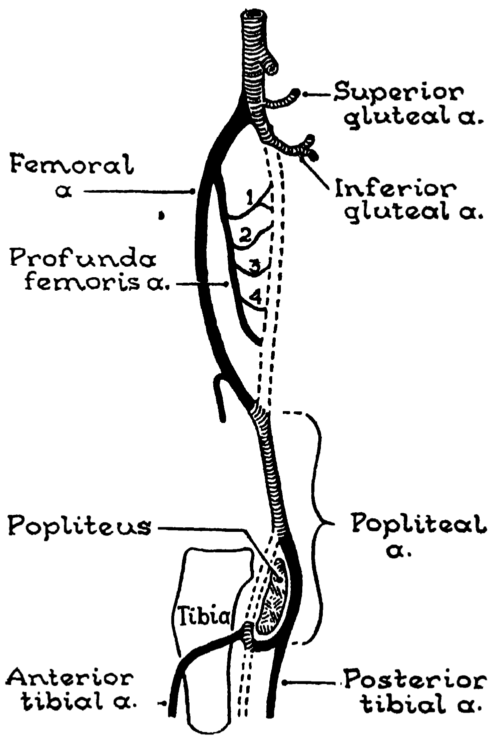


FIG. 414. Development of the main arterial trunk: (hatched segments are primary; solid black are secondary; clear disappear). (After Senior.)

the primary trunk in front of it is superseded. Occasionally the definitive popliteal artery passes in front of the Popliteus, that is, it pursues the primary route.

It is desirable that main arteries should lie at flexures, such as the groin, back of the knee, arm pit, and front of the elbow, where they receive natural protection.

THE LEG AND THE DORSUM OF THE FOOT

The leg or crural region is the segment of the lower limb between the knee and the ankle. It is conveniently subdivided into four regions:

1. The anterior crural (anterior tibiofibular) region.
2. Posterior crural (posterior tibiofibular) region.

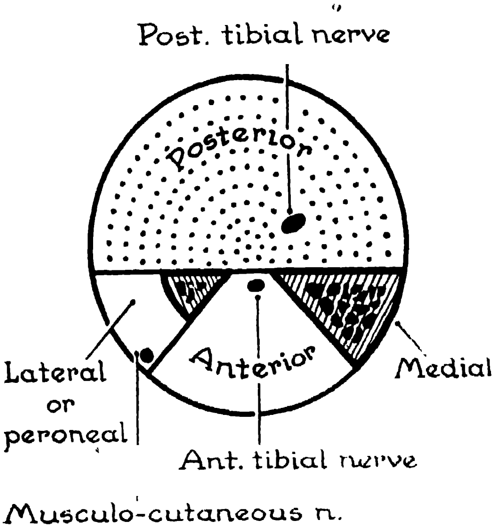


FIG. 415. Scheme of the 4 regions of the leg on transverse section, showing their relative sizes and their nerves. (After H. A. Cates.)

3. Lateral crural (fibular or peroneal) region.
4. Medial crural region (overlying the medial surface of the tibia).

The boundaries of these regions are well seen in a transverse section through the middle of the leg (*fig. 416*). The posterior region is much larger than the anterior because it contains the powerful muscles (Gastrocnemius and Soleus) required by extending the ankle joint to raise the body in walking, whereas almost all that is expected of the muscles of the anterior region is that they cause the foot to clear the ground and not let the toes drag during the act of advancing the limb when walking.

The Shaft of the Tibia and the Medial Crural Region. By palpation note that the medial surface of your own tibia is subcutaneous, smooth and flat; that the skin covering it is free; that it passes

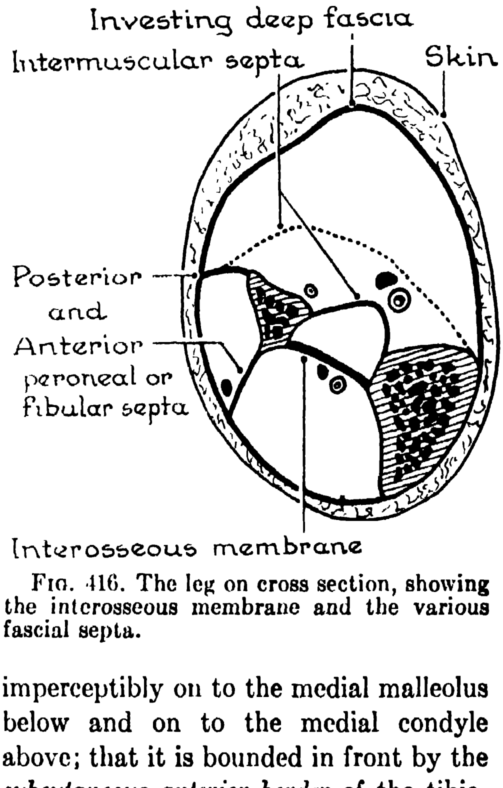


FIG. 416. The leg on cross section, showing the interosseous membrane and the various fascial septa.

imperceptibly on to the medial malleolus below and on to the medial condyle above; that it is bounded in front by the *subcutaneous anterior border* of the tibia, which may be traced from the anterior border of the medial malleolus to the tubercle of the tibia; and that it is bounded behind by the *subcutaneous medial border* of the tibia, which may be traced from the posterior border of the medial malleolus to the horizontal groove

on the medial condyle for the insertion of the Semimembranosus (*fig. 417*).

THE TENDINOUS EXPANSIONS of the Sartorius, Gracilis, and Semitendinosus find attachment to the medial surface of the tibia below the level of the tubercle. Each represents a different region of the

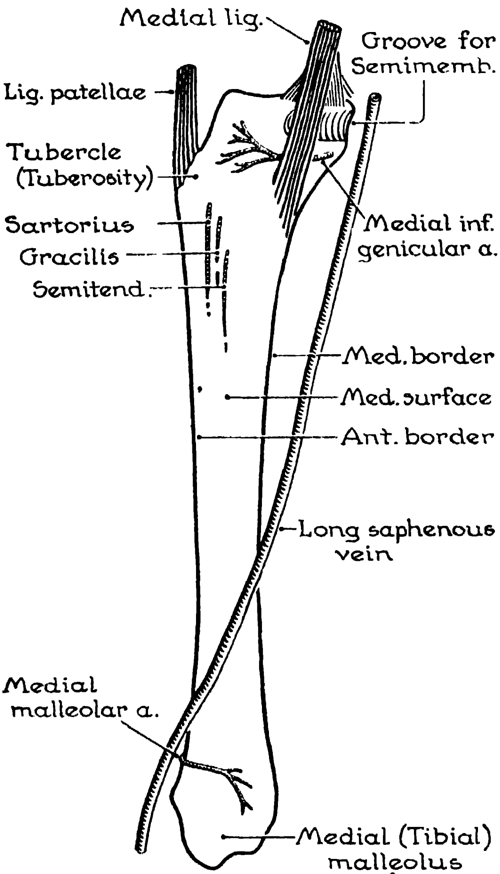


FIG. 417. The subcutaneous or medial aspect of the tibia.

thigh; each is supplied by a different nerve (femoral, obturator, or sciatic); each passes across the medial ligament of the knee to reach its insertion, a bursa intervening. The Sartorius, approaching from the front of the thigh, is naturally superficial to the Gracilis, which approaches from the medial side; and the Gracilis is in turn superficial to the Semitendinosus, which belongs to the back of the thigh. These 3 all obviously flex the knee joint and rotate the leg medially; and obviously they act to better advantage when the movement of flexion is well established than during its initial stages.

On pressing the back of your heel against the leg of the chair you are sitting on, you can by palpation identify the four tendons on the medial side of the knee. The rounded tendon of the Semitendinosus, which is the lowest and most lateral of these, and the massive tendon of the Semimembranosus are identified with ease; the lower edge of the Gracilis with care; the Sartorius, which crosses the femur just behind the adductor tubercle, with difficulty.

THE MEDIAL LIGAMENT OF THE KNEE (tibial collateral lig.) stretches in a fan-shaped manner from the medial epicondyle of the femur, situated half-an-inch below the adductor tubercle, to the upper margin of the medial condyle of the tibia; but its more superficial fibers, formerly part of the Adductor Magnus, extend as a broad band beyond this to a rough marking in front of the medial border of the tibia at the level of the insertion of the three tendons. Like the cord of a bow, this band bridges both the groove on the medial condyle to which the Semimembranosus tendon is attached and the hollow below the condyle in which pass the *medial inferior genicular vessels and nerve* (*fig. 418*). You should certainly plot out the course of the medial ligament by connecting its sites of attachment.

The *medial malleolar vessels* cross the medial surface of the tibia above the malleolus. The *long saphenous vein* and its companion, the *saphenous nerve*, cross the lowest third of the medial surface of

the tibia obliquely and continue proximally, about half an inch behind the medial border, as far as the knee. At the knee they lie a hand's breadth behind the medial border of the patella (p. 373). The vein arises from the medial end of the dorsal venous arch of the foot; the nerve, appears between the Sartorius

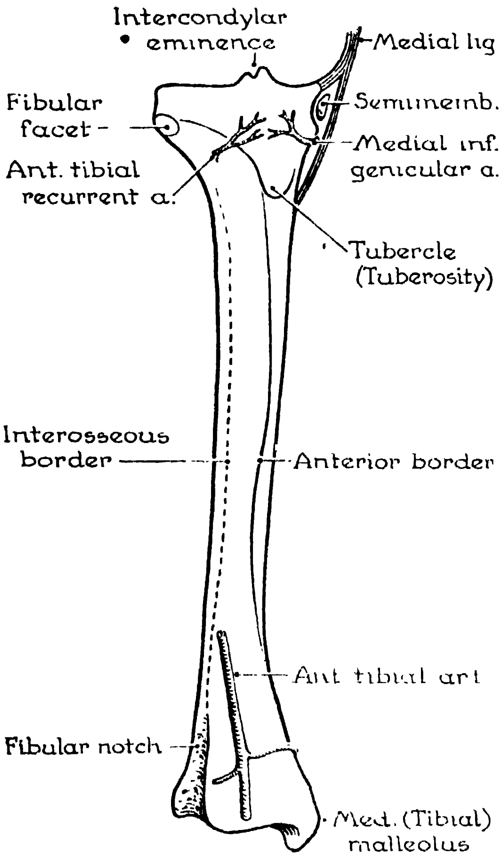


FIG. 418. The lateral aspect of the tibia.

and Gracilis, accompanies the vein through the leg, and ends half way along the medial side of the foot; and, though many of its twigs pass deep to the vein, some pass superficially.

The shaft (body) of the tibia is thinnest and most readily fractured at the junction of its lowest third with its upper two thirds.

TERMINOLOGY. The shaft of the tibia is triangular on cross-section, and, like other long bones (p. 3), it is described as having 3 surfaces separated by 3 borders (*fig. 419*). An anterior border, "the shin"—which it obviously possesses—implies a posterior surface; a medial surface implies a lateral border; and a lateral surface implies a medial border. But the medial surface faces antero-medially, and the lateral surface, antero-laterally; so these surfaces may optionally be called antero-medial and antero-lateral. In this case, the medial border would require to be referred to as the postero-medial,

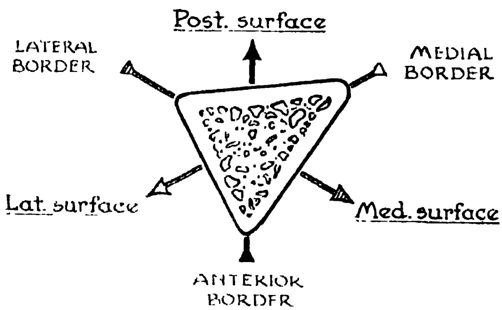


FIG. 419. Terminology: surfaces and borders are named by opposites.

and the lateral as the postero-lateral. But, to refer to either of these borders as the posterior border without further qualification would result in ambiguity.

The Lateral Border of Tibia. Because the *lateral border* gives attachment to the interosseous membrane, which unites the fibula to the tibia, it is sharp and is legitimately referred to as the *interosseous border* (*fig. 418*). This sharp lateral or interosseous border extends from near the small, flat, circular facet on the lateral condyle, where the head of the fibula articulates, to the deep, rough, triangular notch for the reception of the lower end of the fibula. The fibula requires to be firmly united to the tibia at its lower end, otherwise the talus

would prize the two bones apart; so, the interosseous border splits to form the sides of the triangular *fibular notch;* and the interosseous membrane is thickened to form a strong interosseous ligament; so, the notch is rough. The *lower end of the tibia* is expanded in order to offer a large bearing surface to the talus. And, the appearance of a 4th surface (the fibular notch) transforms the triangular cross-section into a quadrangular one. [The lower end of the femur is similarly enlarged and quadrangular; its fourth or additional surface being the popliteal surface, whose sides are formed by the splitting of the linea aspera into the epicondylar lines.] The fibular notch together with the deflection of the anterior border, due to the change in direction of the Tibialis Anterior (see below), causes the lateral surface of the tibia to come to face anteriorly in its lowest quarter.

The lateral surface is limited above by the epiphyseal line, which arching upwards and laterally from the tubercle to below the fibular facet, serves to separate this surface from the lateral condyle. The prominent overhanging ridge it creates, affords attachment to the fascia of the anterior crural region. The Tibialis Anterior, the only muscle attached to the lateral surface of the tibia, arises from the upper two-thirds of this surface by fibers which being fleshy leave no mark.

The posterior surface (p. 426).

The Anterior Tibio-fibular Region and the Dorsum of the Foot. These two regions are structurally continuous; so, they will be considered together. The boundaries of the anterior tibio-fibular region are: the lateral surface of the tibia, the interosseous membrane, the anterior surface of the fibula, the anterior peroneal septum and the investing deep fascia (*fig. 416*).

The Great Arterial Trunk of the front of the leg and dorsum of the foot, accompanied by venae comitantes, enters the anterior osseo-fascial compartment in contact with the medial side of the neck of the fibula, and ends near the web between the great and 2nd toes by dividing into dorsal digital branches for the adjacent sides of these toes. A fairly straight line joining these two points crosses the ankle joint midway between the two malleoli and defines the course of the great arterial trunk (*fig. 420*). It lies literally on the "skeletal plane", crossing in turn the interosseous membrane, the lowest third of the lateral surface of the tibia, the ankle joint, the talus, the talo-navicular joint, the navicular, the naviculo-cuneiform joint, the middle cuneiform, and the fascia covering the first dorsal interosseous muscle. At the ankle joint it changes its name from *anterior tibial a.* to *dorsalis pedis a.*: at the proximal end of the first intermetatarsal space it sends a large *profunda branch* into the sole of the foot and changes its name to the *first dorsal metatarsal a.;* and at the distal end of the space it divides into 2 *dorsal digital* branches.

If all the five muscles in this region are stripped from their attachments and removed, the arterial stem and all its named branches—(this excludes the cutaneous and muscular ones)—are left undisturbed. The undisturbed branches are:

The anterior tibial recurrent artery.
The branch accompanying the musculo-cutaneous nerve.
The medial and lateral malleolar aa.
The medial and lateral tarsal aa.
The arcuate artery.

The *anterior tibial recurrent artery* with the anterior tibial recurrent nerve runs upwards to the lateral condyle to take

part in the genicular anastomoses. To expose it, the Tibialis Anterior must be severed to the bone. A *slender branch*

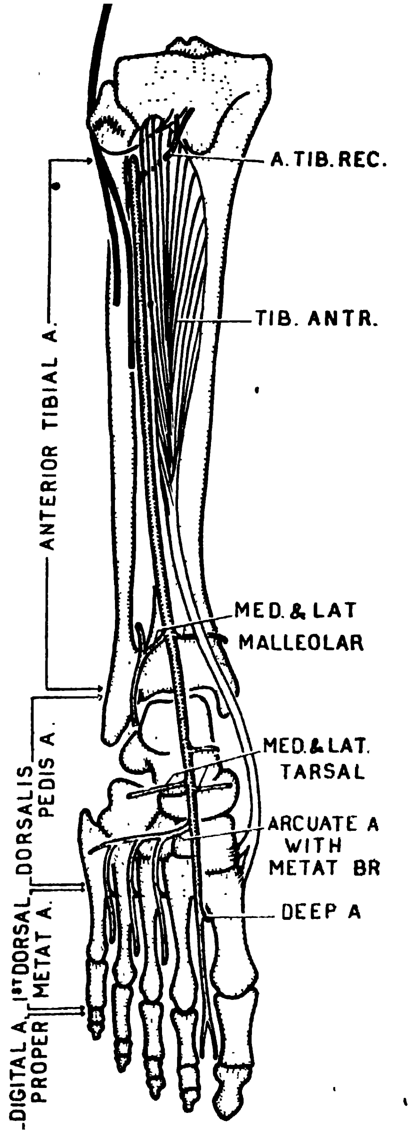


FIG. 420. The great arterial trunk and its named branches lie on the skeletal plane.

passes deep to the anterior peroneal septum to join the musculo-cutaneous (superficial peroneal) nerve. The *lateral malleolar a.* joins the perforating branch of the peroneal a., which enters this region by piercing the lower part of the interosseous membrane. The common stem thus-formed runs downwards in front of the inferior tibio-fibular joint to take part in the anastomoses on the lateral side of the ankle. The *lateral tarsal a.* and the *arcuate a.* run laterally on the dorsum of the foot deep to the Extensor Digitorum Brevis. The *dorsal metatarsal branches* to the 2nd, 3rd, and 4th spaces arise from the arcuate a.; each is joined by a perforating branch of the deep plantar arch; and each in turn divides into proper digital branches. The medial side of the 1st toe and the lateral side of the 5th toe receive digital branches from the 1st and 4th metatarsal arteries respectively. Hence, the arrangement of vessels on the dorsum of the foot is almost identical with that on the dorsum of the hand.

It is to be remembered that during the early embryonic weeks, when the limbs are taking form, blood vessels, in the form of an anastomosing network of capillaries, sprout into them. One or more channels through this network is selected to be the main artery; the rest of the network either disappears or remains in part as branches of this artery (*fig. 421*). Nature is curiously consistent in the paths she singles out. The force of the blood behind the chosen path eventually causes the artery to straighten, presumably for the same reason that the force of water straightens a hose pipe. If, however, some of the branches are firmly anchored, as they are on the foot, the artery may be compelled to take an angular or zig-zag course. The dorsalis pedis a. affords a good example of erratic selection, for it commonly deviates lateralwards and thus comes to occupy a position lateral to its accompanying nerve.

The anterior tibial artery resembles the saphenous artery in that it may fail to grow more than a short way down the leg, in which case the dorsalis pedis artery springs from the perforating branch of the peroneal artery (*fig. 435*).

The Lateral Popliteal Nerve (COMMON PERONEAL N.). This subfascial nerve, after following the posterior border of the Biceps tendon and crossing the Plantaris, lateral head of the Gastrocnemius, and back of the head of the fibula from which it is separated by a film of Soleus, comes finally into direct contact with the lateral side of the neck of the fibula where it divides into *three terminal branches:*

1. Anterior tibial recurrent nerve
2. Anterior tibial nerve
   (Deep peroneal nerve)
3. Musculo-cutaneous nerve
   (Superficial peroneal nerve)

These 3 nerves take origin on and—save for their terminal cutaneous branches—literally never leave the skeletal plane. Mark this! Branches 1 and 2 curve round the neck of the fibula deep to all the structures they encounter, namely: the posterior peroneal septum, Peroneus Longus, anterior peroneal septum, and Extensor Digitorum Longus, and then part company.

The small branch, called the *anterior tibial recurrent nerve*, joins the artery of the same name and sends twigs to the knee joint and to the Tibialis Anterior.

The Anterior Tibial Nerve approaches the anterior tibial artery from the lateral side and accompanies it through the leg; thereafter it accompanies the dorsalis pedis and 1st dorsal metatarsal aa. through the foot and, becoming cutaneous, divides into *two digital nerves*, which accompany the corresponding arteries along the adjacent sides of the 1st and 2nd toes. It supplies the 4 muscles in the anterior crural region, and on the dorsum of the foot it sends a lateral branch to supply the Extensor Digitorum Brevis and the various joints.

The Musculo-cutaneous Nerve runs obliquely downwards and forwards, in contact with the shaft of the fibula and covered by the Peroneus Longus, till it meets the anterior border of the Peroneus Brevis which conducts it to the surface. This it reaches along the line of the anterior peroneal septum, a variable distance above the apex of the subcutaneous triangular area at the lower end of the fibula (*fig. 425*). It supplies the Peroneus Longus and Peroneus Brevis, and sends digital branches to all the toes, save the adjacent sides of the 1st and 2nd (*ant. tibial n.*) and the lateral side of the 5th (*sural n*).

FIG. 421. Arteries are formed from channels through a network.

The Muscles. As may be seen in the cross-sections (*figs. 422, 423*), there are two fleshy muscles, ***Tibialis Anterior*** and ***Extensor Digitorum Longus***, in the upper part of the region; and two more fleshy muscles, ***Extensor Hallucis Longus*** and ***Peroneus Tertius***, in the lower part. At the ankle these are represented by their four tendons. The muscles arise

from the walls of the compartment by fleshy fibers; so, they leave no marks on the bones. The Tibialis Anterior takes origin from the tibia; the other 3 arise from the fibula; only one muscle, the *Extensor Digitorum Brevis,* arises on and confines itself to the dorsum of the foot.

The *Tibialis Anterior* arises from the lateral condyle and upper two-thirds of the lateral surface of the tibia and from

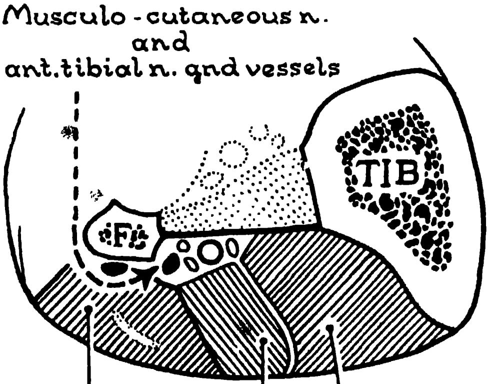


FIG. 422. Section through the upper third of the front of the leg. There are two muscles in the anterior region; one in the lateral. The vessels and nerves cling to the skeletal plane.

the adjacent part of the interosseous membrane and investing deep fascia.

Incise the deep fascia longitudinally and note the muscle fibers arising from it. You will then appreciate why the upper part of the deep fascia is strong, its fibers largely longitudinal, and the upper part of the anterior border of the tibia sharp.

The stout tendon of the Tibialis Anterior turns medially to be inserted by two slips into the adjacent parts of the medial surface of the 1st metatarsal and 1st cuneiform. The tendon fashions the lower part of the anterior border of the tibia, which, accordingly, turns medially; and, because the deep fascia is not attached here, the border is rounded.

The *Extensor Digitorum Longus* is a thin, unipennate muscle. It arises from the entire length of the narrow anterior surface of the fibula and from adjacent parts of the interosseous membrane, anterior peroneal septum, and deep fascia. It is inserted by means of dorsal expansions into the distal two phalanges of the lateral four toes. Its lowest quarter, known as the *Peroneus Tertius,* fails to reach the toes, but it gains attachment anywhere along the dorsum of the (4th or) 5th metatarsal. It is a special evertor of the foot, and is almost peculiar to man.

The *Extensor Hallucis Longus* arises from the middle two-quarters of the anterior surface of the fibula and from the interosseous membrane. It is inserted into the base of the ungual phalanx of the hallux. It is the only muscle to cross the main artery in the leg.

The *Extensor Digitorum Brevis* arises from the anterior part of the upper surface of the calcaneum and from the extensor retinaculum. Its four tendons pass to the medial four toes: the tendon to the hallux crosses the dorsalis pedis artery and is inserted into the base of its proximal phalanx; the other three tendons join the dorsal expansions of the Extensor Digitorum Longus to the 2nd, 3rd, and 4th toes. The fleshy belly of the Brevis is responsible for the soft swelling seen in life on the dorsum of the foot two inches or so in front of the fibular malleolus. Deep to it lie the lateral tarsal and arcuate arteries and the lateral branch of the anterior tibial nerve. Its tendon to the hallux is the only muscle to cross the dorsalis pedis artery.

The Deep Fascia. In the uppermost

part of the front of the leg the deep fascia gives origin to muscles; so, its fibers run longitudinally, are strong, and cause the corresponding part of the anterior border of the tibia to be sharp. In the middle part it gives origin to no muscle; so, it is weaker. In the lowest part and in the ankle region it acts as retinacula (*fig. 54, p. 74*) which prevents the tendons from bowstringing; so, the fibers are disposed circularly, like an anklet, and are strong. On the dorsum of the foot the fascia is thin.

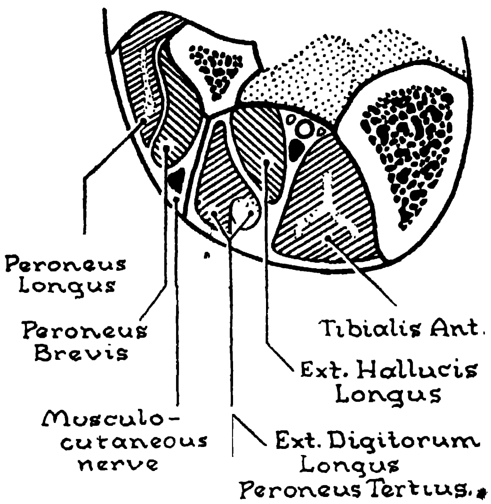


FIG. 423. Section through the lower third of the front of the leg: There are four muscles in the anterior region; two in the lateral.

The Extensor Retinaculum is in two parts—a superior and an inferior (*fig. 424*). The *superior part* (transverse crural lig.) is a transverse band, one or two inches deep. Laterally, it is attached to the anterior border of the triangular subcutaneous area of the fibula; medially, it passes over the anterior border of the tibia, just above the malleolus, and blends with the periosteum. This explains why the anterior border of the fibula is here sharp and why that of the tibia is here rounded. In this is found one of the few exceptions to the generalisation that where fascia encounters bare bone it unites with it. The *inferior part* (crucial crural lig.) is placed in front of the ankle region and has the appearance of a Y-shaped band. The stem of the Y is attached to the anterior part of the upper surface of the calcaneum; the upper limb blends with the periosteum on the medial malleolus; and the lower limb blends with the plantar fascia. The deeper fibers of the Y form 2 loops or slings—one for the Perineus Tertius and Extensor Digitorum Longus; the other for the Extensor Hallucis Longus. The function of the loops is to prevent the tendons from bowstringing forwards and also from bowstringing medially. Of this you can satisfy yourself by noting the angular course taken by the tendons when the foot is inverted. The Tibialis Anterior tendon which, during dorsiflexion of the ankle joint, is the most prominent tendon in the region, is attached so far back on the

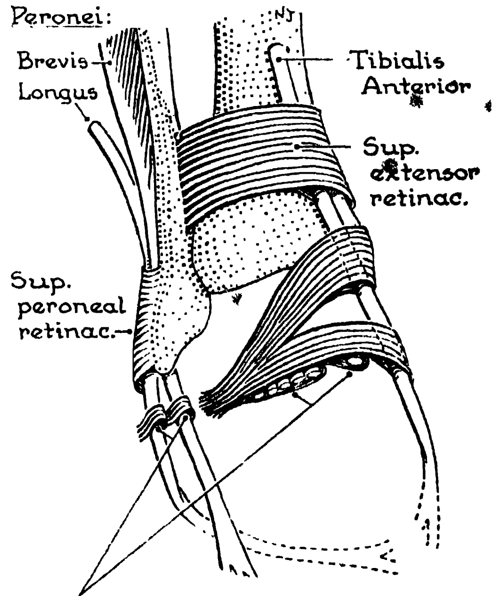


FIG. 424. The extensor and peroneal retinacula.

side of the foot that it hardly requires restraining. Indeed, the limbs of the retinaculum commonly pass deep to it.

The Inferior Peroneal Retinaculum may be likened to the stem of the Y relayed laterally to the peroneal tubercle and beyond it. It consists of 2 loops—the upper loop holds the Peroneus Brevis to the peroneal tubercle; the lower loop bridges the Peroneus Longus tendon and extends from the tubercle postero-inferiorly to be attached to the lateral surface of the calcaneum. (Superior peroneal retinaculum, p. 432.)

Synovial sheaths that extend about an inch proximal and distal to the points of friction envelop the tendons.

The Lateral Crural Region (Fibular or Peroneal Region). PALPABLE PARTS. By palpation of your own limb you can determine the following points: The upper and lower ends of the fibula are subcutaneous; the body is buried in muscles. The fibula is not parallel to the tibia but is set obliquely to it. The *head of the fibula* is rounded and a blunt *apex* or *styloid process* rises from its posterior part. The *lateral popliteal* (common peroneal) *nerve* can be rolled behind the head. The *malleolus* is triangular; its anterior and posterior borders are conspicuous and palpable; and its *blunt apex* descends from the posterior border. Its lateral surface is subcutaneous and is uninterruptedly continuous with a subcutaneous area on the shaft, shaped like an isosceles triangle. The *apex of the subcutaneous triangle* is three or four inches above the malleolus, and it leads to the anterior peroneal septum which is attached to the anterior border of the fibula. The musculocutaneous nerve becomes cutaneous along the line of the septum. The cord-like *lateral ligament of the knee* runs obliquely downwards and backwards to be attached to the head of the fibula, just in front of its apex. It can be felt when the knee is flexed but not when it is extended, because the *Biceps* then covers it. The cord-like *calcaneo-fibular ligament* is attached to the malleolus of the fibula, just in front of its apex. It also runs obliquely downwards and backwards. It can be mapped out but not palpated, because it is crossed by the long and short peroneal tendons.

Muscles. The *Peronei Longus et Brevis* fill the lateral crural compartment. They arise from the lateral aspect of the fibula and slightly from the anterior and posterior peroneal septa. The Peroneus Longus arises from the upper two-thirds of the compartment; the Peroneus Brevis from the lower two-thirds; and they overlap each other in the middle third. The two muscles are similar in structure, each being bipennate in its upper half and unipennate in its lower half (*fig. 425*). The Brevis is inserted into the dorsum of the base of the 5th metatarsal beyond its tip. The Longus enters the sole of the foot behind the base of the 5th metatarsal, runs in the groove on the lateral and under surfaces of the cuboid, and is inserted into the same two bones as the Tibialis Anterior, but on their lateral aspects. With the Tibialis Anterior it forms a stirrup for the foot. The Brevis is, therefore, anterior to the Longus in the leg and above it on the side of the foot. It is easily seen that the tendon of the Brevis fashions the posterior aspect of the fibular malleolus and of the subcutaneous area above it. The fibular malleolus plays the part of a pulley for the two Peronei; so, it is rounded posteriorly and is grooved by their tendons. Both tendons cross the calcaneo-fibular ligament of the ankle joint. They are bound down by the superior and inferior peroneal retinacula. Behind the malleolus and below it, the two tendons lie within a single synovial

sheath; at the peroneal tubercle, the sheath bifurcates and envelops each tendon separately for an inch or more. The sheath for the Peroneus Longus may

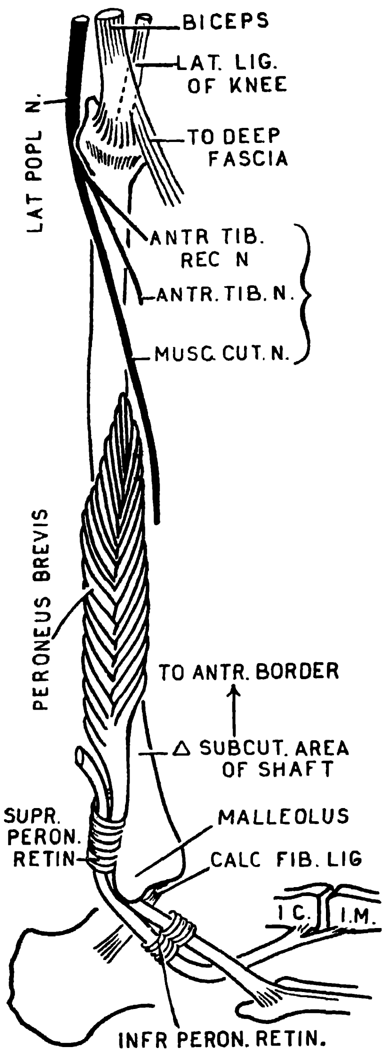


FIG. 425. The peroneal or lateral crural region.

or may not be continuous with the sheath wrapped around it in the sole.

The Functions of the Fibula. In amphibia the fibula is as large as the tibia. It articulates with the femur above and with the tarsus below and it is weight supporting. In reptiles it is smaller than the tibia and it bears less weight. In monotremes and marsupials it is still further reduced. In horses and ruminants the shaft of the fibula either disappears or is represented by a fibrous

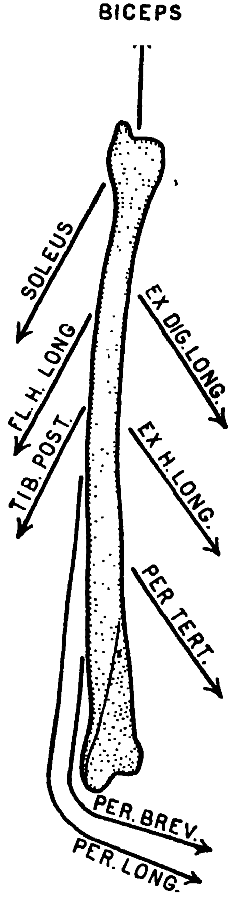


FIG. 426. The muscles attached to the fibula pull downwards—except the Biceps.

band that connects the upper and lower ends; and the ends are either incorporated *with the tibia or in articulation with it.* In carnivora and primates the complete fibula exists, but it does not bear weight. Only in man does the fibular malleolus descend below the level of the tibial malleolus.

In man the functions of the fibula are three-fold:

1. It gives origin to muscles.
2. It forms an elastic side for the socket for the talus.
3. It acts as a pulley for the tendons of the Peronei.

Nine muscles are attached to the fibula. Of these the Biceps pulls upwards, the other eight pull downwards (*fig. 426*).

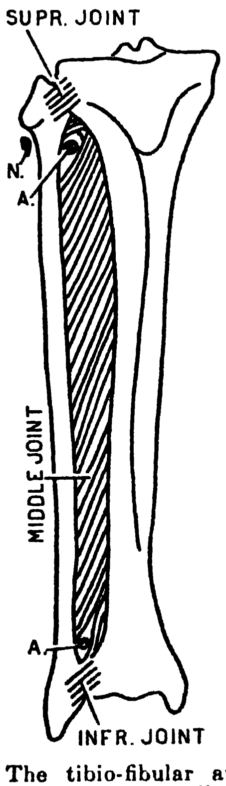


FIG. 427. The tibio-fibular articulations. The fibula is moored to the tibia by fibers, practically all of which resist the downward pull of the muscles. They do not prevent the fibula from being forced upwards.

All ligamentous connections between tibia and fibula are so directed as to resist this downward pull, i.e., they pass downwards and laterally and constitute a functional unit (*fig. 427*).

The Tibio-fibular Joints. The fibula is anchored to the tibia at its upper end, along its shaft, and at its lower end; so, there are three tibio-fibular joints—a superior, a middle, and a lower.

The Superior Tibio-fibular Joint has a synovial cavity and is of the arthrodial or gliding variety. A small, flat, round facet on the head of the fibula articulates with a similar facet on the postero-lateral part of the lateral condyle of the tibia. A capsule with very strong anterior fibers encloses the cavity. Behind the joint is the Popliteus tendon, separated by the Popliteus bursa. The bursa may bring this joint and the knee joint into communication (*fig. 486*). In front it is practically subcutaneous, though a few fibers of the Peroneus Longus and Extensor Digitorum Longus cover it.

The Middle and Inferior Tibio-fibular Joints are syndesmoses. The *interosseous membrane* or middle joint extends down the respective sides of the tibia and fibula, producing a sharp line on each. Below, each line expands into a large, rough, triangular area which is concave on the tibia (fibular notch) to receive the corresponding convex area on the fibula. The rough triangular area on the shaft of the fibula is separated from the smooth, triangular facet on the fibular malleolus, which articulates with the talus, by a horizontal strip of cartilage. It is obvious that union must here be strong in order to prevent lateral displacement of the talus; so, the interosseous membrane expands to form an *interosseous ligament* which binds the opposed triangular areas together. In addition, a strong anterior band, and a very much stronger posteri one, called the *anterior* and *posterior inferior tibio-fibular ligaments* (ant. and post. ligs. of the lateral malleolus), stretch from the margins of the fibular notch of the tibia to the adjacent borders of the fibular malleolus. A long band, the *transverse tibio-fibular ligament*, stretches

from the posterior margin of the inferior articular surface of the tibia to the malleolar fossa of the fibula.

Functions. All the ligaments mentioned above have a common direction. They prevent the fibula from being pulled down by the muscles, but they allow it to be forced upwards, or upwards and laterally, as happens in extreme dorsiflexion of the ankle. This yielding or suppleness gives strength to the ankle joint and is more desirable than rigidity.

Relations. The peroneal artery descends behind the joint; its perforating branch descends in front of it. (*Fig. 435.*)

Shaft of the Fibula (*fig. 428*). The shape of the shaft depends largely on the muscles and septa attached to it. It is easiest to begin with the peroneal surface The *peroneal surface* is found by placing a finger behind the malleolus, which is the pulley for the Peronei, and letting it run up the shaft to the head of the bone. This surface is broad and spiral and it is bounded by lines, the *anterior* and *posterior borders*, which give attachment to the anterior and posterior peroneal (intermuscular) septa. To make doubly sure of the anterior border, which separates the peroneal and extensor surfaces, place a finger on the subcutaneous, isosceles triangle above the malleolus and run the finger straight upwards to the head of the bone. The *extensor surface* faces consistently forwards and is almost linear, because it gives origin to the unipennate Extensor Digitorum Longus in its upper three quarters and to the Peroneus Tertius in its lower quarter. It broadens somewhat in its middle two quarters to afford origin to the Extensor Hallucis Longus. The *posterior* or *flexor surface* is broad and it gives origin to the Soleus in its upper third and to the Flexor Hallucis Longus in its lower two-thirds. It is spiral, like the peroneal surface next to it. The *area for the Tibialis Posterior* is the enigma; it is fusiform and is to be found thus: put a finger on the rough area for the interosseous ligament—that is, the area above the smooth, triangular facet on the malleolus that articulates

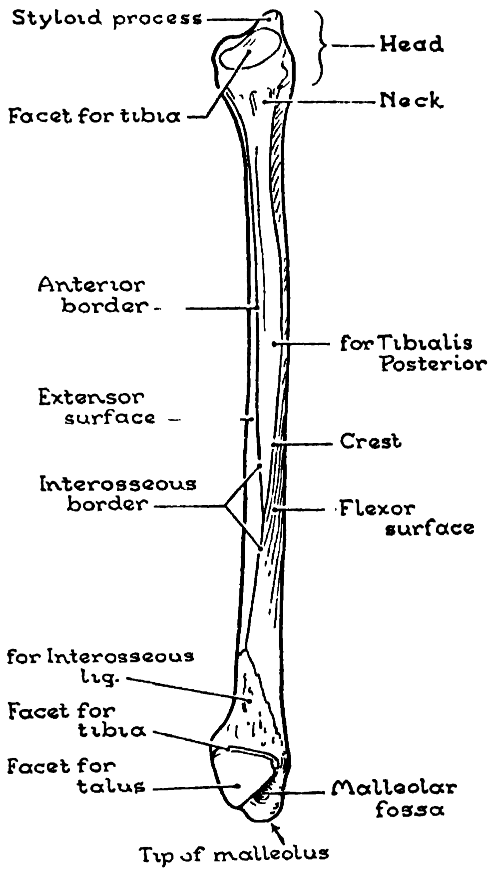


FIG. 428. Medial aspect of the fibula.

with the talus—and follow it upwards. It becomes a line which splits, one third to one half of the way up the shaft, into an *anterior line* and a *prominent posterior crest.* These enclose a fusiform area for the Tibialis Posterior. The anterior line is the *interosseous border* for the interosseous membrane; the prominent crest is for the fascia covering the Tibialis Poste-

rior. It is a common and natural mistake to regard the prominent posterior crest as the interosseous border.

There is a deep hollow, the *malleolar fossa*, between the grooved pulley behind the malleolus and the triangular facet for the talus.

Ossification. The shaft of the fibula ossifies about the eighth fetal week, like the shafts of other long bones. The upper end begins to ossify about the 5th year and fuses about the 19th. The lower end begins to ossify about the 2nd year and fuses about the 18th. The epiphyses, therefore, break the rule of ossification which says the epiphysis with most work to do starts early and ends late (*fig. 429*). This departure is explained by the fact that the upper epiphysis is not a pressure epiphysis in man but a traction epiphysis, like that of the upper end of the ulna; so, it appears late, and it cannot fuse until the tibia stops growing, because it is joined to it. The nutrient foramen is directed downwards away from the more actively growing end.

THE BACK OF THE LEG

(posterior tibio-fibular region)

The Bony Framework of the back of the leg: In a restricted sense, this is the posterior surface of the tibia and fibula below the popliteal region, but exclusive of the fibular malleolus and of the area just above it which the Peronei cover. In the wider sense and for practical purposes, all skeletal parts visible from behind, from the popliteal surface of the femur distally, should be taken into account with this region.

Note the following features—you may consider sketching them: The *femoral condyles* project backwards; they are a thumb's breadth apart; their posterior surfaces are articular and oval. The *epicondylar lines* descend to the *epicondyles*. The *adductor tubercle* rises from the lower end of the medial epicondylar line. The *lower epiphyseal line of the femur* runs through the adductor tubercle

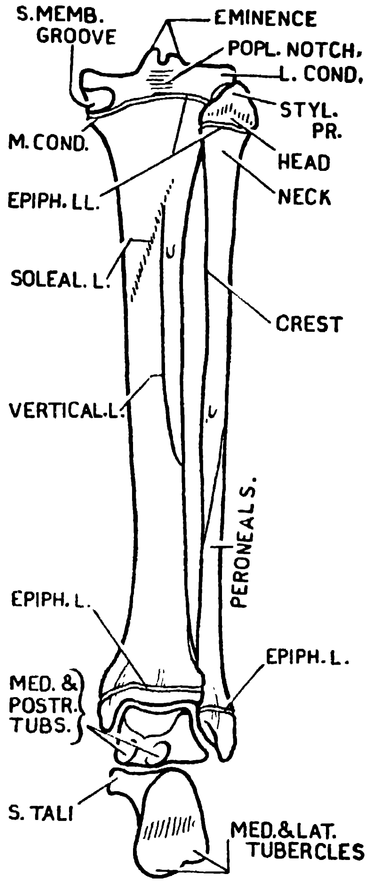


FIG. 429. Posterior aspect of the bones of the leg and foot.

and along the *intercondylar line*. The *tibial condyles* overhang the shaft of the tibia posteriorly and at the sides, but not in front. The *upper epiphyseal line of the tibia* runs half-an-inch below the upper surface (*fig. 429*). The horizontal *semimembranosus groove* occupies the hinder part of the epiphysis of the medial condyle. The round *fibular facet* occupies

the hinder part of the epiphysis of the lateral condyle. The rounded *head of the fibula*, supported by its neck, ends in an apex or *styloid process* which fails to rise to the level of the knee joint. The smooth, flat, posterior surface of the body of the tibia, narrowest at the junction of its upper $\frac{3}{4}$ and lower $\frac{1}{4}$, is crossed by an oblique, rough line, the *soleal line*, from which a *vertical line* descends in the middle $\frac{1}{3}$ of this surface The *nutrient* or *medullary foramen*, which is the largest in the body, is directed away from the knee, thus indicating that the upper end of the tibia grows more than the lower end. The fibula is so twisted spirally that the *surface that faces posteriorly above* faces medially below, and the *surface that faces laterally above* faces posteriorly below. This is owing to the fact that the Peronei wind on to the back of the *fibular malleolus* and utilize it as a pulley. The *tibial malleolus*, which also plays the part of a pulley, is $\frac{3}{4}''$ shorter than the fibular malleolus.

The following parts of the talus and calcaneum are in view: The rapidly narrowing hinder part of the *upper articular surface* of the talus ends at a *deep groove* placed between the *posterior* and *medial tubercles* of the talus. The groove lodges the Flexor Hallucis Longus tendon and, therefore, runs downwards and medially. It is continuous above with a faint groove on the lower end of the tibia midway between the malleoli; and below with a decided groove on the under surface of the sustentaculum tali. The *posterior third of the calcaneum* projects backwards beyond the talus and forms the prominence of the heel. The upper surface of this third of the bone is saddle-shaped. The posterior surface is convex from above downwards, and is narrow above and broad below where it ends in a large medial tubercle and a small lateral one. Only the medial one rests on the ground.

One part of the fibula belonging to this region is not visible from behind: it is the part that gives origin to the Tibialis Posterior. It occupies the middle three-fifths of the shaft between the interosseous border in front and a prominent crest behind.

Muscles. The muscles of the posterior crural region are much larger and more powerful than those of the anterior crural region, because they are required to sustain the whole weight of the body when one rises on the toes in walking (*fig. 430*).

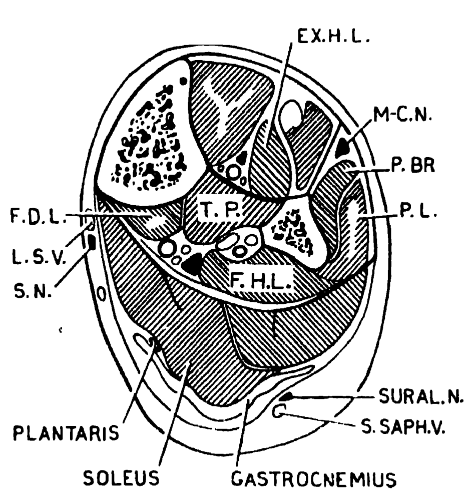


FIG. 430. Transverse section through middle of leg.

The muscles are disposed in 2 groups, a superficial and a deep:

Superficial group:

(1) Gastrocnemius
(2) Plantaris
(3) Soleus

The Gastrocnemius has two bellies which form the side boundaries of the lower half of the popliteal fossa. The Soleus arises at the lower limit of the fossa. The Plantaris is placed between them. All 3 are inserted into the heel,

which they raise in walking. They are supplied by the medial popliteal n., near their upper borders.

Deep group:

(1) Flexor Hallucis Longus and

(2) Flexor Digitorum Longus (pass to the end phalanges of five toes)

(3) Tibialis Posterior (passes to all the small tarsals and most metatarsals)

THE **Gastrocnemius** has two flattened heads of origin which are largely tendinous. The lateral head arises from the epicondyle of the femur just above the impressions for the Popliteus and lateral ligament of the knee; the medial head arises from the popliteal surface of the femur, above the medial condyle. The two resulting fleshy bellies are united by a fibrous line at the bottom of a deep furrow which lodges the short saphenous vein and the cutaneous branch of the medial popliteal nerve. The bellies end at the middle of the leg in a broad aponeurosis that blends with the aponeurosis of the Soleus to form the *tendo calcaneus* or tendo Achillis. The two bellies of the Gastrocnemius account for the fullness of the calf. The Gastrocnemius and Soleus are referred to as the Triceps Surae (Sura, L. = the calf). A *bursa* between the tendon of the Semimembranosus and the medial head of the Gastrocnemius communicates with a *bursa* between the latter and the capsule of the knee joint. This in turn may communicate with the knee joint (in 42.4% of 528 dissecting room limbs). So, fluid in the joint, resulting say from a sprain, can in this circumstance pass from the knee joint via the Gastrocnemius bursa into the Semimembranosus bursa and cause a swelling at the back of the knee. A *sesamoid bone* is commonly found in the lateral head of the Gastrocnemius, and less commonly in the medial head.

The tendon of Achilles and the ligamentum patellae are comparable (*fig. 431*). They are approximately equal in length. Each is inserted into the intermediate ⅗ of an epiphysis, the lower ⅕ of which is subcutaneous, while the upper ⅕ has a subtendinous bursa. There is a large pad of fat between the bursa and the capsule of the nearest joint. Superficial to the lig. patellae is the superficial infrapatellar bursa; superficial to the tendo Achillis there may be a bursa. The Soleus is more powerful than the Gastrocnemius, and it contributes more to the thickness of the tendon. Its fleshy fibers are inserted into the deep aspect of the tendon to within an inch of the calcaneum.

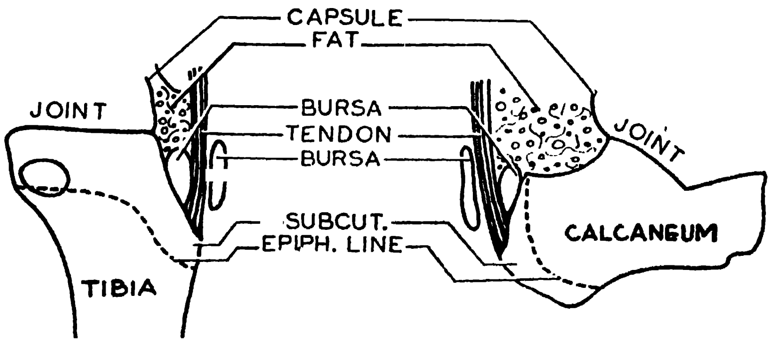


FIG. 431. The tendo calcaneus and ligamentum patellae compared.

THE **Plantaris** is placed between the Gastrocnemius and the Soleus. It has a fleshy part, the size of an Interosseous

muscle, and a tendon about a foot long. It arises near the lateral head of the Gastrocnemius and it is inserted along the medial side of the tendo Achillis. In lower mammals (monkey, rabbit, dog) it is a large muscle whose tendon runs in a groove behind the calcaneum on its way to the toes, which it flexes. In plantigrade man it is divided by the calcaneum into a *sural* and a *plantar* part. The sural part is vestigial and, like its homologue the Palmaris, is variable in its attachment and is sometimes absent

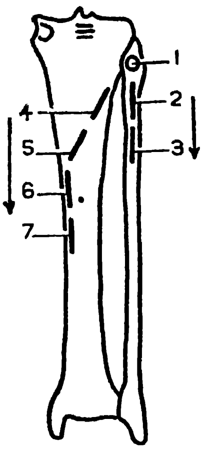


FIG. 432. The increasing origin of the Soleus is horseshoe-shaped.

(p. 31). The plantar part has become the plantar aponeurosis, and, as such, has assumed the duties of a tie for the longitudinal arches of the foot.

THE **Soleus** is shaped like the sole of a boot. In the monkey its origin is limited to the back of the head of the fibula; in man it extends on to the upper third of the posterior surface of the fibula, spreads across the posterior tibial vessels and nerve and acquires attachment to an oblique line on the tibia and to the medial border of the tibia for a variable distance below the oblique line (*fig. 432*). So, it has a *horseshoe-shaped origin.* Short fleshy fibers pass from tendinous septa in the muscle to the aponeurosis that covers its posterior surface. On this aponeurosis the Gastrocnemius plays before joining it to form the tendo calcaneus, just as the Rectus Femoris plays on the Vasti. The anterior fasciculi of the Soleus are bipennate.

THE DEEP MUSCLES. *Above the horseshoe-shaped origin* of the Soleus, the Popliteus is inserted into the posterior surface of the tibia by fleshy fibers. As shown in

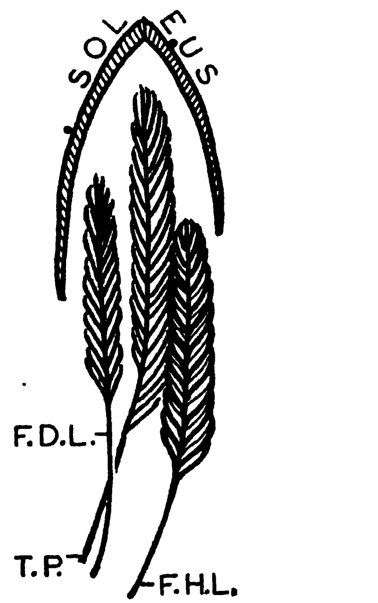


FIG. 433. Three bipennate muscles resembling three plumes.

figure 434, the *Popliteus* arises by tendon from the lateral epicondyle of the femur, runs backwards between the lateral ligament of the knee and the lateral semilunar cartilage, and occupies the groove behind the superior tibio-fibular joint before passing to its insertion. The *oblique line* of the tibia is rough medially, but less distinct laterally. It owes its presence mainly to the Soleus, whose origin is fibrous, and partly to the medial fibers of the fascia covering the Popliteus which are strong and vertical because they form

part of the insertion of the Semimembranosus (*fig. 435*). *Below the horseshoe-shaped origin* are three bipennate muscles which recall the three plumes that surmount the motto "Ich Dien" (*fig. 433*). The three plumes are of unequal length: the middle one (Tibialis Posterior) is the longest; the medial one

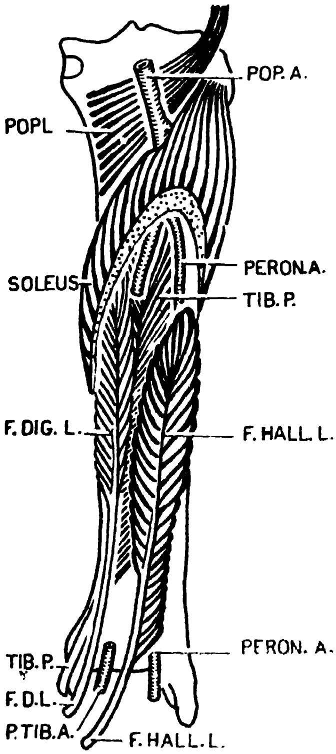


FIG. 434. The deep muscles of the back of the leg—above the horseshoe-shaped origin of the Soleus and below it. The course of the artery.

(Flexor Digitorum Longus) is intermediate in length; while the lateral one (Flexor Hallucis Longus) is the shortest. The tendons of these three muscles are, then, the quills of the plumes; and in passing downwards and medially to enter the sole of the foot they groove the lower end of the tibia.

There are, in fact, 5 tendons behind the ankle region. Of these, 2, the Peronei Brevis et Longus, groove the back of the fibular malleolus; 2, the Tibialis Posterior and Flexor Digitorum Longus, groove the back of the tibial malleolus; and one the Flexor Hallucis Longus, grooves the lower end of the tibia midway between the malleoli (*fig. 434*). The malleoli are, in so far as these tendons are concerned, not "little hammers" but pulleys.

THE **Tibialis Posterior** arises from the upper two-thirds of the interosseous membrane and from the bone on each side of it, namely, from the medial surface of the fibula and from the posterior surface of the tibia lateral to the vertical line. Its upper limit is at the superior tibio-fibular articulation. Its tendon inclines medially to reach its pulley, which is the medial malleolus, and in so doing it leaves the lower part of this surface of the tibia uncovered. From its origin in the leg to its insertion in the foot the Tibialis Posterior clings faithfully to the skeletal plane (*figs. 457, 461*).

The fascia covering the posterior surface of the Tibialis Posterior is in large measure an aponeurosis of origin for the Fl. Digitorum Longus; so, its fibers run downwards and medially from a crest on the fibula to the vertical line on the tibia.

THE **Flexor Digitorum Longus** arises from the posterior surface of the tibia below the oblique line and medial to the vertical line, and from the fascia covering the Tibialis Posterior. Its tendon crosses the Tibialis Posterior tendon superficially behind the medial malleolus.

THE **Flexor Hallucis Longus** is inserted into the terminal phalanx of the great toe—the toe off which one rises when walking and running—consequently, like the Soleus, it acquires an extensive origin. Not content with the limited surface the fibula has to offer, the origin of the Flexor Hallucis Longus encroaches upon every adjacent territory;

thus—it gains attachment laterally to the posterior peroneal septum; medially to the fascia covering the Tibialis Posterior, and in so doing it spreads across the peroneal artery, which consequently runs through a tunnel in this muscle; below the level at which the Tibialis Posterior becomes tendinous, its fleshy fibers seize the opportunity to gain attachment to the interosseous membrane and to the tibia as far down as is functionally possible. And, when the Soleus fails to occupy its allotted part of the upper third of the fibula, the Flexor Hallucis Longus commonly creeps up on to it. There would, indeed, seem to be a struggle between these two muscles, so important to man, for possession of this disputed territory. The muscle is so bulky it overlaps and largely conceals the fleshy part of the Tibialis Posterior. Its tendon grooves the lower end of the tibia midway between the two malleoli.

Arteries and Nerves. There are two great arteries and one nerve in this region, namely:

The posterior tibial artery
The peroneal artery
The posterior tibial nerve

The **Posterior Tibial Nerve** is the continuation of the medial popliteal nerve, the change in name takes place where the Popliteus ends and the Soleus begins, i.e., at the soleal or oblique line of the tibia. It lies between the two arteries, closely applied to the lateral side of the posterior tibial artery. All three travel distally behind the fascia covering the Tibialis Posterior, and, when this muscle inclines medially, they continue their courses on the skeletal plane. The *posterior tibial nerve* takes a straight course, crosses the posterior tibial artery and gains its lateral side. It supplies the three deep bipennate muscles and the deep part of the Soleus (which also is bipennate) and it ends deep to the flexor retinaculum (laciniate lig.) by dividing into the medial and the lateral plantar nerve.

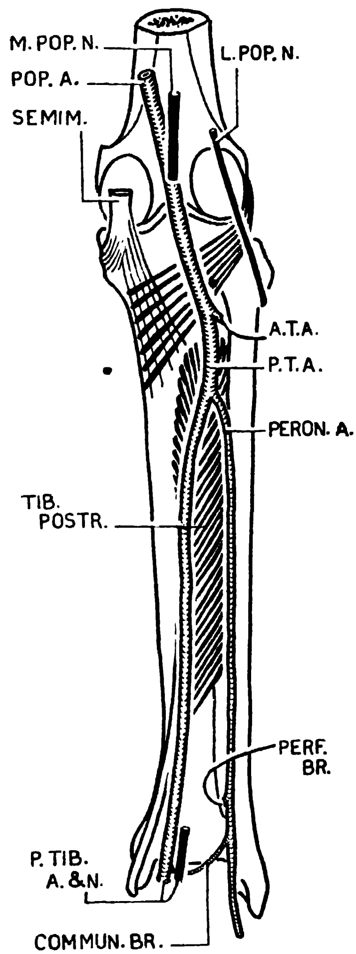


Fig. 435. The arteries and nerves of the back of the leg.

The **Posterior Tibial Artery** is the larger of the two terminal branches of the popliteal artery. It begins at the upper border of the Soleus, and ends deep to the flexor retinaculum by dividing into the medial and the lateral plantar artery. Venae comitantes and the posterior tibial nerve accompany it. The Flexor Digitorum Longus lies medially; the Flexor

Hallucis Longus lies laterally; the fascia covering the Tibialis Posterior, the shaft and lower end of the tibia, and the capsule of the ankle joint lie anteriorly. The Soleus is superficial to it above; near the ankle two layers of fascia cover it. When this fascia is relaxed by inverting the foot, the pulsations of the artery can be felt the breadth of two tendons (Tibialis Posterior & Fl. Digitorum Longus) from the border of the medial malleolus.

THE **Peroneal Artery** arises from the posterior tibial artery before the latter is crossed by the posterior tibial nerve. It descends first behind the fascia covering the Tibialis Posterior and lies deep to the Flexor Hallucis Longus, which has spread across it; it then continues downwards behind the fibula, inferior tibio-fibular joint, and ankle joint, and ends on the lateral surface of the calcaneum as the lateral calcanean artery.

Branches. Both the posterior tibial artery and its peroneal branch have *muscular*, *cutaneous*, *medullary*, *communicating*, and *calcanean* branches. The medullary branch of the posterior tibial artery enters the tibia below the soleal line. It is the largest of all medullary arteries to long bones. The medullary branch to the fibula is small and comes from the peroneal artery. Both medullary canals are directed away from the more actively growing ends of the bones —the knee ends. The communicating branch unites the peroneal and posterior tibial arteries behind the lower end of the tibia, and in the absence of the proximal end of either artery it may become a main channel. The peroneal artery ends as the lateral calcanean artery described. The posterior tibial artery and its lateral plantar branch give off medial calcanean branches which perforate the flexor retinaculum and supply the medial and inferior aspects of the heel. The peroneal artery gives off a perforating branch which pierces the interosseous membrane, runs down in front of the inferior tibiofibular joint, and anastomoses on the lateral side of the ankle. When the anterior tibial artery fails to reach the ankle (in 3.5 per cent of 536 limbs), the dorsalis pedis artery springs from the perforating peroneal artery.

To expose the two arteries and nerve at operation, you would require to work from the medial side of the leg, because the Flexor Hallucis Longus is so large and overlapping (*fig. 430*).

Deep Fascia. The deep fascia at the back of the leg is in several sheets: (1) the investing layer, (2) the intermuscular layer between the Soleus and the 3 deep bipennate muscles, (3) the layer covering the Tibialis Posterior, and (4) the layer covering the Popliteus. The last two have been described.

The *investing deep fascia* is attached to the medial border of the tibia and posterior border of the tibial malleolus medially; and to the posterior peroneal septum and, through it, to the fibula laterally. No muscle arises from it; and it is not thick, except at the ankle where it forms strong medial and lateral bands, the *flexor retinaculum* and *superior peroneal retinaculum*. These stretch postero-inferiorly from the tibial and fibular malleoli respectively to the corresponding sides of the calcaneum.

The *intermuscular layer* of fascia between the Soleus and the three deep bipennate muscles is limited above and at the sides by the horseshoe-shaped origin of the Soleus; below, it forms an anklet which holds in place the five deep tendons at the back of the ankle; so, it is strong and is composed of transversely placed fibers. It is owing to the narrowing of the Soleus to form the tendo Achillis that the intermuscular layer

comes to the surface and blends with the investing deep fascia and reinforces the flexor and superior peroneal retinacula (*fig. 436*).

The Short Saphenous Vein drains the lateral end of the dorsal venous arch of the foot. It runs below the lateral malleolus, along the side of the tendo Achillis, between the two heads of the Gastrocnemius, and, after piercing the popliteal fascia, ends partly in the popliteal vein and partly in the profunda femoris vein.

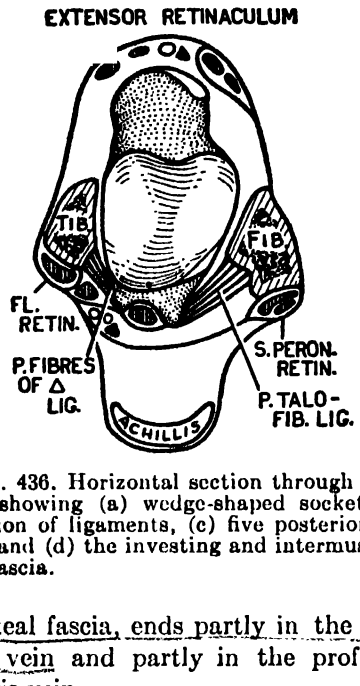


FIG. 436. Horizontal section through ankle joint showing (a) wedge-shaped socket, (b) direction of ligaments, (c) five posterior tendons, and (d) the investing and intermuscular deep fascia.

The cutaneous veins of the leg form an open anastomotic network between the long and short saphenous veins, and they communicate along the intermuscular septa with the deep veins. Above the ankle the valves in the communicating veins are so directed that the blood flows from the superficial veins into the deep veins, and from the short saphenous vein into the long saphenous vein.

The Cutaneous Nerves are: terminal twigs of the (1) posterior cutaneous nerve of the thigh, (2) medial cutaneous nerve of the thigh, and (3) obturator nerve (sometimes), all three of which end in the proximal part of the calf; (4) twigs of the saphenous nerve throughout the medial side of the leg; (5) the cutaneous branch of the medial popliteal (tibial) nerve, called the *sural nerve*, which descends in the furrow between the two heads of the Gastrocnemius and is joined at a variable level by (6) a cutaneous branch of the lateral popliteal (peroneal) nerve, called the *communicating sural n.* The sural nerve continues with the short saphenous vein along the lateral border of the tendo Achillis, below the lateral malleolus, and along the lateral border of the foot to end as the digital nerve to the lateral side of the little toe. It anastomoses with the musculo-cutaneous nerve and commonly takes over part of its territory. The patterns formed by these nerves are numerous.

THE FOOT

The Bones of the Articulated Foot. The study of the bones of the foot is too often undertaken as a difficult and unpleasant task. It is believed that if the student will give thought to the remarks describing the accompanying diagrams, verify the statements by referring to an articulated foot, and make use of his own foot to study the surface relations, he will find himself familiar in a practical way with the important details of the foot; and, when he comes to read in the text-book descriptions of the individual bones, he will find that he is able to anticipate much of what is written. He can, of course, test his own knowledge by reproducing the diagrams.

Examine the dorsum of an articulated foot and make the following observations:

1. *Outline.* The medial border of the foot is almost straight; the most projecting toe is the big toe, or quite commonly

the 2nd; the little toe projects the least; and the lateral border converges on the rounded heel (*fig. 437*).

2. The line joining the midpoints of the medial and lateral borders of the foot is oblique. In front of it lie the metatarsal

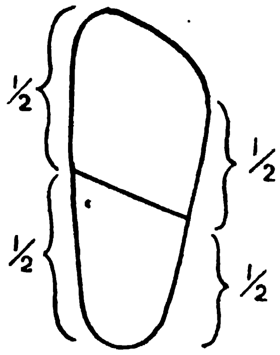


Fig. 437. The outline of the foot.

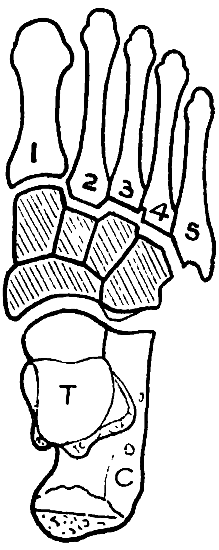


Fig. 438. The dorsum of the foot.

bones and phalanges; behind it lie the tarsal bones. The tarsals are short or cubical bones and are described as having 6 surfaces (their borders are ignored). The metatarsals and the proximal phalanges are long or cylindrical bones with a body and two ends. The middle and ungual phalanges, though developmentally long bones with epiphyses at their proximal ends, are in reality nodular and rudimentary; those of the little toe are commonly fused together. That this degeneration of the little toe is not due to the wearing of boots is shown by the fact that it occurs in the feet of primitive peoples who wear no constricting footgear. Of the metatarsals, the 1st is the stoutest and strongest; the 2nd projects fore and aft the metatarsals on each side of it; the 5th has a pointed, projecting base (*fig. 438*). The hallux has but two phalanges both of which are stout. *Metatarsals* are told from metacarpals by their length and side to side flattening. The 1st is rounded medially and dorsally, in conformation with the transverse arching of the foot; its lateral surface is flat; its base is kidney-shaped. The student commonly refers it to the wrong side of the body. The phalanges, not being prehensile, are small.

3. *The Transverse Tarsal Joint.* The movements permitted at the ankle joint are flexion and extension; it is a hinge joint. When, therefore, you inturn your foot in order to obtain a view of the sole, that is when you invert your foot, some joint other than the ankle must be involved. It is evident that to permit of this rotatory motion a joint or joints in which convex surfaces are in articulation with concave surfaces are requisite. This condition is found where the head of the talus, which is globular, fits into the posterior surface of the navicular, which is cup-shaped; and where the anterior surface of the calcaneum, which is cut away infero-medially, articulates with the posterior surface of the cuboid, which, being the counterpart, has a backwardly projecting process called the *calcanean angle* or *process*. It is at these joints, the *talo-navicular* and *calcaneo-cuboid*, collec-

tively known as the transverse tarsal joint, that movements of inversion and eversion take place; they augment the movements at the talo-calcanean joints.

4. *The 3 "Units" of the Foot.* The obliquely placed tarso-metatarsal articulation and the concavo-convex transverse tarsal joint of inversion and eversion serve to divide the foot into three units: an anterior, a middle, and a posterior (*fig. 439*).

The Posterior Unit comprises the two large tarsal bones: (a) talus, and (b) os calcaneum (*figs. 440, 441*).

The Talus rests on the anterior two-thirds of the calcaneum and projects slightly in front of it. It has a body, neck, and head. The upper surface of the body supports the tibia, is entirely articular, and is saddle-shaped. The sides of the body are grasped by the per surface of the body supports the tibia, is entirely articular, and is saddle-shaped. The sides of the body are grasped by the malleoli, and the facets that result correspond in length and shape with those of the malleoli. The posterior surface of the body is restricted to two tubercles, a *medial* and a *posterior*, separated by a groove for the Flexor Hallucis Longus tendon and, therefore, running downwards and medially. The upper surface of the neck is rough. The head is rounded in front to articulate with the navicular bone.

The *Os Calcaneum* is large and oblong. It is divided into $\frac{3}{3}$. The anterior $\frac{2}{3}$ supports the talus; the posterior $\frac{1}{3}$ forms the prominence of the heel and rests on the ground. The anterior surface is wholly in articulation with the cuboid. The posterior third of the upper surface is saddle-shaped, horizontal, and free; the intermediate third is oblong, convex, articular, and oblique; the anterior third forms a non-articular horizontal plat-

FIG. 439. The three "units" of the foot.

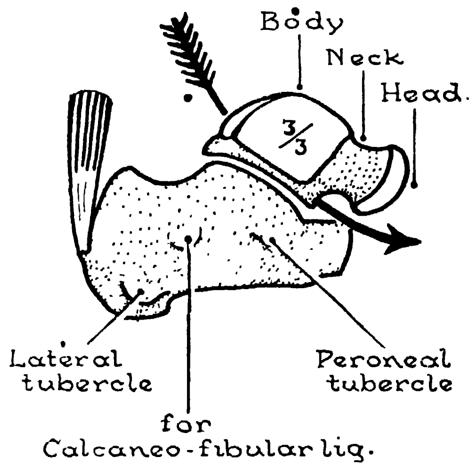


FIG. 440. The lateral aspects of the talus and os calcaneum. The arrow traverses the tarsal tunnel.

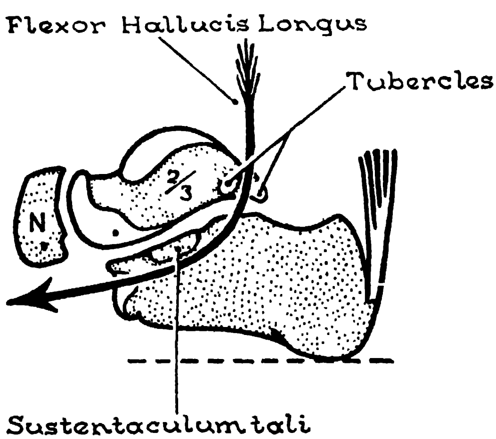


FIG. 441. The medial aspects of the talus and os calcaneum.

form laterally, and has a small facet medially for the head of the talus. This facet may *or may not* be continuous with a facet on a medially projecting shelf, the *sustentaculum tali*. Pass a probe through the tunnel between talus and calcaneum. Enter it behind the sustentaculum and observe that it passes downwards and laterally and debouches on to the anterior third of the upper surface of the calcaneum. The lateral surface is almost flat and vertical. [It has, however, a tubercle, the *peroneal tubercle* or trochea, placed half-an-inch below the fibular malleolus and a fulness half-an-inch behind this for the calcaneo-fibular

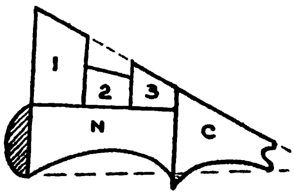


FIG. 442. The middle "unit," comprising the five small tarsal bones, is a modified wedge

ligament.] The medial surface is hollowed out between the sustentaculum and the posterior surface deep enough to receive the thumb. The posterior surface (tuberosity) is non-articular, and it is wider below than above. It is continuous, on the plantar surface, with a large medial tubercle and a small lateral tubercle.

The Middle Unit comprises the five small tarsal bones and roughly resembles a triangle or a wedge whose apex is lateral and base medial (*fig. 442*). The triangle is not geometrically perfect; the anterior side does not present a straight side to the 5 metatarsals, but is indented between the 1st and 3rd cuneiforms to receive the base of the 2nd metatarsal which is morticed between them. This morticing locks the bone and prevents side to side shifting of the anterior unit of the foot. The posterior side, when viewed from behind, is seen to be doubly concave; so, it allows of inversion and eversion of the middle unit on the posterior unit. The blunt apex, formed by the lateral surface of the cuboid, is grooved for the tendon of the Peroneus Longus. The base, where formed by the medial surface of the navicular, presents a tuberosity; where formed by the medial surface of the medial cuneiform, it is not distinctive but merely forms a part of the arched dorsum of the foot.

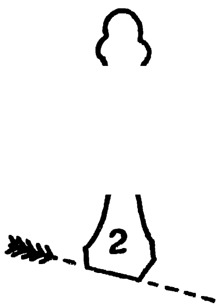


FIG. 443. The base tells the side.

5. If you accept the following generalization and apply it, you will have no difficulty in converting *figure 442* into the shaded part of *figure 438*. *Two continuous articular facets never, or hardly ever, lie in precisely the same plane; even when two facets on one bone are continuous with one another, they always, or almost always, meet at an angle, that is they form inclined planes.*

On putting this to the test you find that the anterior surface of the navicular presents to the cuneiforms not one plane but three; and that the medial surface of the cuboid presents to the navicular and lateral cuneiform not one plane but two. Again, the base of the 2nd metatarsal fits not into a square recess but into an obtuse angled one; and the bases of the

3rd, 4th, and 5th metatarsals occupy not one plane but three different planes, for the lateral cuneiform projects beyond the cuboid, and the facets on the cuboid for the 4th and 5th metatarsals are inclined to one another. Hence, the oblique anterior surface of the wedge interlocks with the bases of the metatarsals.

The *postero-lateral angles of the bases* of the 2, 3, 4, and 5th metatarsals point to the sides to which they belong (*fig. 443*); not so the base of the 1st metatarsal. Its posterior surface is concave from side to side, suggesting that it once possessed a lateral hinge movement and that, like the great toe of the ape, it was at one time used for prehensile purposes.

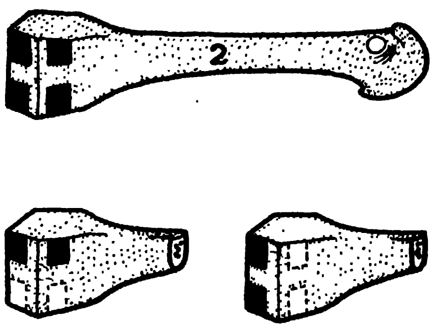


Fig. 444. Variations in metatarsal facets.

The *contiguous sides of the bases* of the lateral four metatarsals have articular facets. But there are no such facets between the bases of the 1st and 2nd metatarsals, thus indicating further that the great toe was once a free member like the thumb.

The 2nd metatarsal is morticed between the medial and lateral cuneiforms; hence, the antero-posterior facets on the 2nd metatarsal and 2nd cuneiform that face the 3rd metatarsal and 3rd cuneiform do not occupy a single plane, but three. The facets on the medial side of the base of the 4th metatarsal for the 3rd cuneiform and 3rd metatarsal are nearly, but not quite, flush with each other. To the generalization enunciated above there is, then, no exception in the foot.

This interlocking of the various bones results in an increase in the stability of the foot; it prevents side-shifting of the bones, and to that extent it is beneficial (*fig. 445*). In this there is probably nothing basic; it occurs in obedience to no law, unless it be the law of chance.

6. If the sides of the triangular or wedge-shaped middle unit were straight, then each of the 5 bones comprising it would necessarily be longer medially than laterally. Examination shows that for the cuboid and navicular it is so, but not for the cuneiforms.

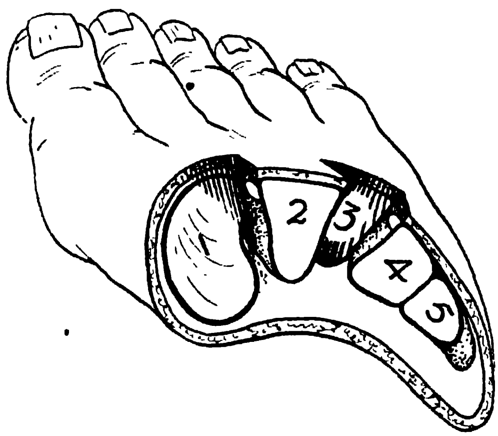


Fig. 445. The bases of the metatarsals interlock with the small tarsals and so prevent side to sideshifting.

7. *Springs.* The foot is described as having two longitudinal arches. It should be remembered that the human foot is designed not for standing, but for walking. It is not a static structure, a piece of masonry, but an active structure. Regard it, then, as a spring rather than as an arch. The three medial digits, their metatarsals and cuneiforms, the navicular and talus, which are collectively known as the *medial longitudinal spring* (arch) of the foot, can be detached from the two lateral digits, their metatarsals,

the cuboid and the calcaneum, collectively known as the *lateral longitudinal spring* (arch) Perhaps it is better to regard the calcaneum as common to both springs (*fig. 446* and *fig. 507*).

The foot is arched not longitudinally only but also transversely, the dorsum being convex both antero-posteriorly and from side to side; the plantar aspect is concave in both directions. Each *transverse spring* or *arch* forms only half an arch; but, when you stand with your feet together a complete arch is formed.

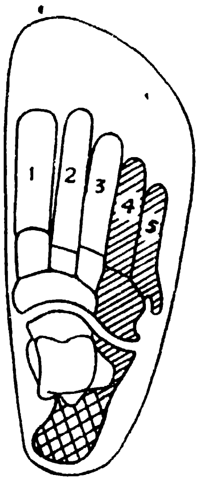


FIG. 446 The medial and lateral longitudinal springs or arches; the calcaneum is common to both.

Have this in mind when you orient a tarsal or a metatarsal bone. Imagine it to occupy its proper position in the system of arches; for example, the dorsal surfaces of the navicular and 1st cuneiform look upwards and medially, of the 2nd and 3rd cuneiform upwards, of the cuboid upwards and laterally. The medial surface of the cuboid faces medially and upwards and supports the lateral cuneiform and the navicular—and so on (*fig. 505*).

8. *Viewed from the lateral side* the foot appears as a low, flat arch of which the posterior pillar is the medial tubercle of the calcaneum; the anterior pillar, the head of the 5th metatarsal (*fig. 447*). Though the cuboid occupies the position of a key-stone, it requires the support of the *Peroneus Longus*, which passes below it. When you place your foot on the ground, the spring will, of course, flatten under your weight of say 150 lbs. This it can do because the anterior and posterior surfaces of the cuboid are not flat from above downwards, but concave; so,

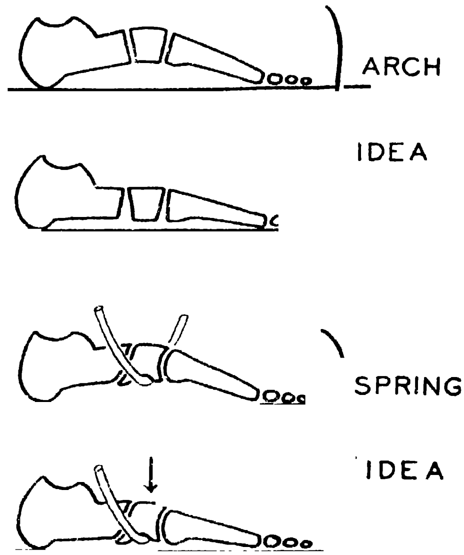


FIG. 447 To demonstrate that the foot should be regarded as a spring rather than an arch

the 4th and 5th metatarso-cuboid joints are hinges like the corresponding joints in the hand. Because the postero-medial angle of the cuboid projects backwards under the calcaneum, which is cut away to receive it, the calcaneo-cuboid joint allows of plantar-flexion; dorsi-flexion is restricted by the upper border of the anterior surface of the calcaneum, which is overhanging.

9. *Viewed from the medial side* the foot appears highly arched. The medial tubercle of the calcaneum forms the posterior pillar; the sesamoid bones under

the head of 1st metatarsal form the anterior pillar (*fig. 448*). The summit of this arch lies at the junction of its posterior one-third and anterior two-thirds. The round head of the talus is placed at the summit, between the sustentaculum tali and the tuberosity of the navicular, and here receives no bony support. But the spring ligament (plantar calcaneonavicular), which extends between these two bony processes, lies below the head and supports it (*fig. 503*). The spring ligament is in turn supported by the tendon of the *Tibialis Posterior*, whose main attachment is to the tuberosity of the navicular.

Identifiable Parts in the Living Foot

Familiarity with the following important bony parts, joint levels, tendons, and vessels of the foot can easily be acquired from a study of your own foot:

a. The blunt end of the medial malleolus,

b. the sustentaculum tali lying a full inch below the malleolus,

c. the tuberosity of the navicular lying $1\frac{1}{2}''$ in front of the sustentaculum, and

d. the head of the talus, occupying the space between these two, are all four easily palpated, and may indeed be rendered visible through the skin. In palpating the tip of the malleolus and the sustentaculum, approach them from below.

e. The position of the joint between the base of the first metatarsal and its cuneiform may be gauged to be the breadth of a cuneiform (say one inch) anterior to the tuberosity of the navicular.

f. The sesamoid bones, which play on the under surface of the head of the 1st metatarsal, may be felt under the ball of the big toe (*figs. 449, 454, 456*).

g. Just distal to them is the 1st metatarso-phalangeal joint. Verify this by flexing the toes when the rounded head of the metatarsal, which is thereby uncovered, may be felt.

h. The lateral malleolus is visible; its pointed end is $\frac{3}{4}''$ lower than the medial malleolus and on a posterior plane.

i. The subcutaneous surface of the lateral malleolus extends like an isosceles triangle for 3 or 4 inches up the shaft of the fibula; and from its apex the submerged anterior border of the bone is continued up the fibula to its head. This

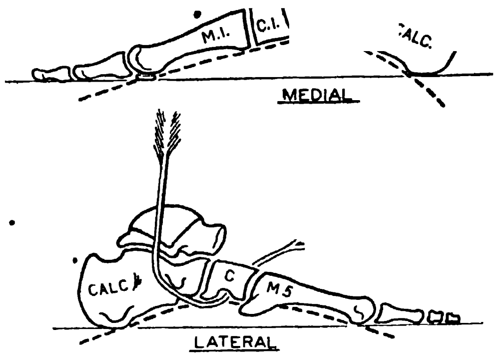


FIG. 448. The medial and lateral longitudinal springs.

border gives attachment to the anterior peroneal septum (*fig. 425*).

j. The projecting base of the 5th metatarsal is easily felt about half way along the lateral border of the foot.

k. The calcaneo-cuboid joint lies $\frac{1}{3}$ of the way between the tip of the lateral malleolus and the projecting base of the 5th metatarsal.

l. Verify this by inverting the foot and palpating the supero-lateral portion of the anterior surface of the calcaneum which is thereby uncovered. This is easily done.

m. With the foot still inverted, palpate the upper part of the front of the head of the talus. It lies just supero-medial to

the front of the calcaneum. The lateral side of its neck also can be felt. It is evident that at these two joints, collectively called the transverse tarsal joint, movements of inversion and eversion take place.

n. Of necessity the muscles of inversion and eversion, the *2 Tibiales* and the *3 Peronei,* must be inserted anterior to the

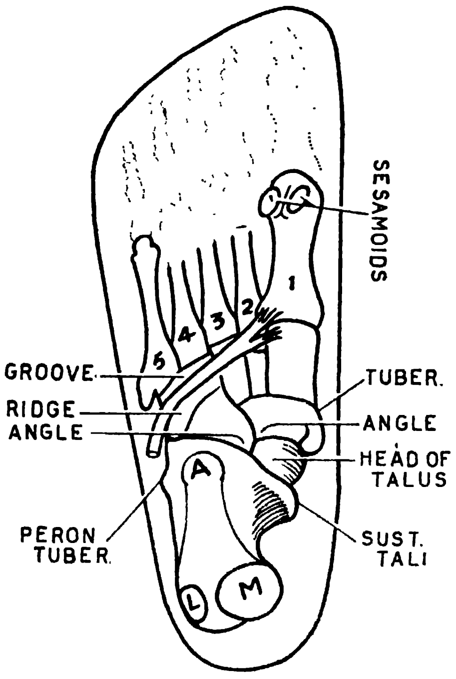


FIG. 449. The chief features of the plantar aspect of the articulated foot.

transverse tarsal joint. With the foot inverted and ankle plantarflexed, the tendon of the Tibialis Posterior may be felt as it passes midway between the medial malleolus and the sustentaculum tali on its way to the tuberosity of the navicular. Here it lies superficial to the deltoid ligament. With the foot inverted and the ankle dorsiflexed, the tendon of the Tibialis Anterior may be observed a inch anterior to the medial malleolus, as it passes towards its insertion into the lower part of the medial surface of the first metatarsal and adjacent part of the 1st cuneiform (*fig. 457*).

o. Now, with the foot everted, trace the tendons of the Peronei Longus et Brevis as they turn forwards below the lateral malleolus; the Brevis to pass to the upper surface of the base of the 5th metatarsal, the Longus to pass into the sole of the foot in the groove on the cuboid, and therefore just behind the base of the 5th metatarsal. (These two tendons pass superficial to the lateral ligament of the ankle. (*Fig. 425.*)

p. The tendons of the Ex. Hállucis Longus and Ex. Digitorum Longus can generally be made to stand out on the dorsum of the foot.

q. The soft cushion-like mass in front of the lateral malleolus, caused by the relaxed Ex. Digitorum Brevis, is apt to be mistaken for a swelling, the result of a sprain.

r. The pulsation of the anterior tibial artery may be felt midway between the two malleoli where two tendons (Tibialis Anterior and Ex. Hallucis Longus) lie medial to it, and two tendons (Ex. Digitorum Longus and Peroneus Tertius) lie lateral (*figs. 420, 499*).

s. On the dorsum of the foot the pulsation of the dorsalis pedis artery may, perhaps, be made out on the line leading to the first intermetatarsal space. The posterior tibial artery may be felt to pulsate the breadth of two tendons (Tibialis Posterior and Flexor Digitorum Longus) behind the medial malleolus. For success in this, the foot should be slightly inverted (passively) in order to relax the fascia, and you should palpate firmly forwards and laterally (*figs. 404, 461*).

The Sole of the Foot

The Articulated Foot from Below. The 3 units (anterior, middle, and poste-

rior), so conspicuous in the foot viewed from above, are in evidence when viewed from below (*fig. 449*). The features of particular note fall into 3 groups:

1. *Bearing Points.* The foot is sometimes referred to as a tripod and the print made by a wet foot may suggest three bearing points, namely, the *medial tubercle of the calcaneum*, the *head of the 5th metatarsal*, and the *two sesamoid bones* that play one on each side of the V-shaped ridge below the head of the 1st metatarsal (*fig. 450*). These points are, of course, the ends of the longitudinal springs or arches, the posterior point being common to both springs. It was demonstrated by Morton (p. 486) that the heads of all the metatarsal bones are weight-bearing. Indeed, the heads of metatarsals 2, 3, and 4 must bear some weight because the anterior part of the foot is not arched transversely, there being neither ligaments nor muscles to support an arch here. Now, if you will stand barefooted on five strips of paper, about $\frac{5}{8}$ inch wide, placed parallel with the foot under the respective metatarsal heads, and have an assistant attempt to pull the strips from under the foot, you will discover that the foot is no tripod (R. L. Jones).

2. *The Five Processes of the Calcaneum*—three on the plantar surface and one on each side: In addition to the *medial tubercle*, which is large and weight-bearing, a small *lateral tubercle* and a small *anterior tubercle* project from the under surface of the calcaneum but do not reach the ground. A pulley projects from each side of the calcaneum—the *sustentaculum tali* medially, the *peroneal tubercle* laterally. The Flexor Hallucis Longus grooves the under surface of the sustentaculum and subsequently passes between the two sesamoid bones. The Peroneus Longus grooves the side of the calcaneum below the peroneal tubercle and is bound to it by the inferior peroneal retinaculum. Thereafter, it passes obliquely across the sole to the adjacent parts of the 1st metatarsal and 1st cuneiform. It makes a *groove* under the cuboid and therefore a *ridge* also. It crosses the backwardly projecting base of the 2nd metatarsal. It causes this part of the foot to be transversely arched and the base of the 1st metatarsal and the 1st cuneiform to hide the base of the 2nd metatarsal and the 2nd cuneiform.

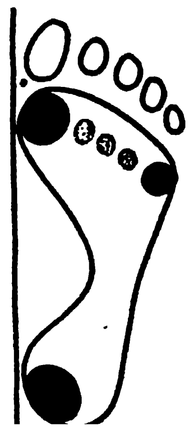


FIG. 450. The foot as a tripod.

3. *The Transverse Tarsal Joint.* The part of the inferior surface of the cuboid behind the ridge is large and triangular. It ends behind in the *calcanean angle*, which lies below the calcaneum, which is cut away to receive it. The under surface of the navicular has an *angle* which is almost on a level with its *tuberosity*. The head of the talus is without bony support between the sustentaculum tali behind and the tuberosity and angle of the navicular in front.

Superficial Structures. The epidermis and dermis are both much thicker on the palms and soles than elsewhere. It is so at birth. With intermittent pressure and friction the thickness becomes

exaggerated. The subcutaneous fat is engaged by tough fibrous strands. Numerous other comparisons can be made between the different structures in the hand and foot (p. 486), between the bones, muscles, vessels, nerves, and fascia.

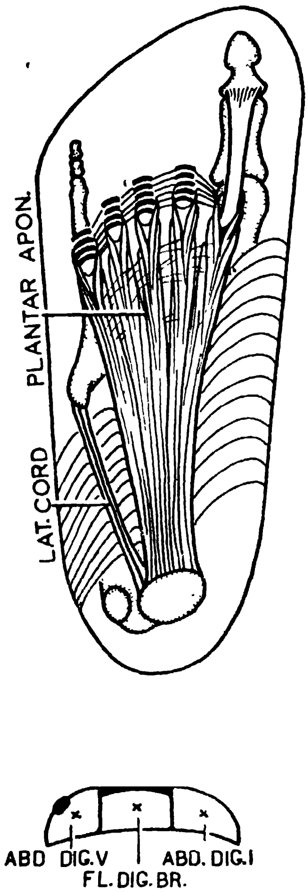


Fig. 451. The plantar fascia.

The cutaneous nerves: The medial plantar nerve supplies the 3½ digits on the hallux side of the foot, just as the median nerve supplies the 3½ digits on the pollex side of the hand, leaving the lateral plantar nerve, which corresponds to the ulnar nerve in the hand, to supply 1½ digits. The skin under the heel is supplied by the medial calcanean branches of the posterior tibial nerve which pierce the flexor retinaculum with their companion arteries. (*Fig. 452.*)

Note. A complete display of the sole can be made by reflecting or excising the *four central structures;* namely, (1) the plantar aponeurosis, (2) the Flexor Digitorum Brevis, (3) the Flexor Digitorum Longus, and (4) the Adductor Hallucis Obliquus; and by so doing you leave the marginal structures intact thereby preserving the outline of the foot.

The Plantar Fascia. In lower mammals the *Plantar Aponeurosis,* or central portion of the plantar fascia, is continuous with the Plantaris behind the calcaneum; in man it has become detached from the sural portion of the Plantaris and modified to act as a strong tie for the longitudinal springs of the foot. Posteriorly, it is attached to the front of the medial tubercle of the calcaneum; anteriorly, it splits into five bands, one for each digit (*fig. 451*). Were this an ideal tie, each band would be attached to the structures on the under surface of the ball of each toe, that is, to the plantar (accessory) ligaments of the metatarso-phalangeal joints. But this is not wholly achieved, because the long and short flexor tendons pass below these joints and carry the intermediate portion of each band before them, leaving only the side portions attached to the plantar ligaments. The *medial* and *lateral portions* of the plantar fascia cover the abductors and short flexors of the great and little toes and are thin, except for one strong *cord* that passes from the medial (sometimes lateral) tubercle of the calcaneum to the tip of the projecting base of the 5th metatarsal. Sometimes this cord is partly fleshy and is then known as the *Abductor Metatarsi Quinti.* As it is the only structure attached to the tip of the fifth metatarsal base, it is

presumably responsible for its shape and direction. The base may have a separate (traction) epiphysis until the fifteenth year called after Vesalius, the *Os Vesalianum.* This cord clearly is a tie for the posterior segment of the lateral spring.

The Muscles of the Sole of the Foot are arranged in four layers. **The First or Superficial Layer of Muscles:**

(1) Flexor Digitorum Brevis (inserted into middle phalanges).
(2) Abductor Hallucis and
(3) Abductor Digiti Quinti (inserted into proximal phalanges).

Each of these lies deep to the plantar fascia encased in a fascial compartment of its own (*fig. 452*). *The Flexor Digitorum Brevis* lies deep to the plantar aponeurosis, and to display it this must be removed. It arises mainly from the three sides of its fascial encasement and slightly from the medial tubercle of the calcaneum. Its mode of insertion is similar to that of its homologue in the hand, the Fl. Digitorum Sublimis (*fig. 138*).

The abductors of the first and fifth digits have a continuous fleshy origin; the *Abductor Digiti V* arising from the front of the lateral and medial tubercles; the *Abductor Hallucis* from the medial side of the medial tubercle as well as from the lower border of the flexor retinaculum (laciniate ligament). Each abductor derives a slight origin from the fascia covering it and from the septum between it and the Fl. Digitorum Brevis. Note that the abductors abduct not metatarsals but digits—the metatarsals are, of course, all firmly bound together and are not capable of being abducted. The insertions are, therefore, into the bases not of the metatarsals, but of the proximal phalanges. Though these two muscles are called abductors, and morphologically they are abductors, they are not employed as such in man, who finds no occasion to abduct his toes, but as elastic ties for their respective springs (*fig. 453*). The fact that they are so well developed indicates that they are of importance.

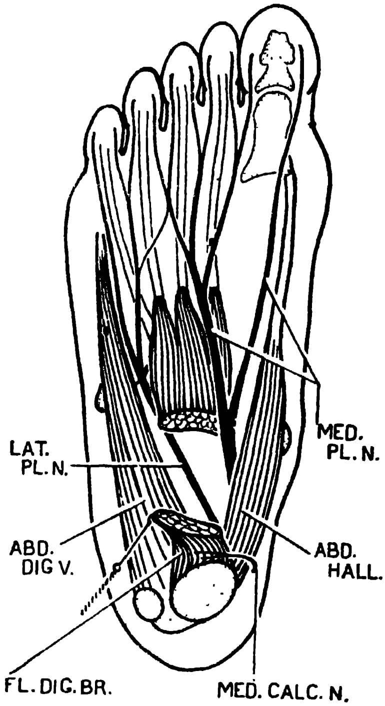


FIG. 452. The first layer of muscles.

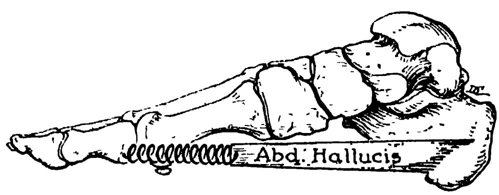


FIG. 453. The short plantar muscles act as elastic springs or ties for the arches of the foot.

The direction of the pull of the fibers of the Abd. Digiti V and the fact that it is inserted more into the under than into the lateral side of the proximal phalanx causes it to behave as a flexor.

The Second Layer of Muscles:

(1) Flexor Digitorum Longus

(2) Flexor Accessorius (Quadratus Plantae).
(3) Lumbricales.
(4) Flexor Hallucis Longus.

To display, the 2nd layer, it is necessary to remove one muscle and one only, the Fl. Digitorum Brevis, and it is wise to retain the two abductors, thereby preserving the outline of the foot. When this is done, the muscles of this layer are seen lying within a triangular frame the sides of which are formed by the abductors, the base by the roots of the five digits (*fig. 454*).

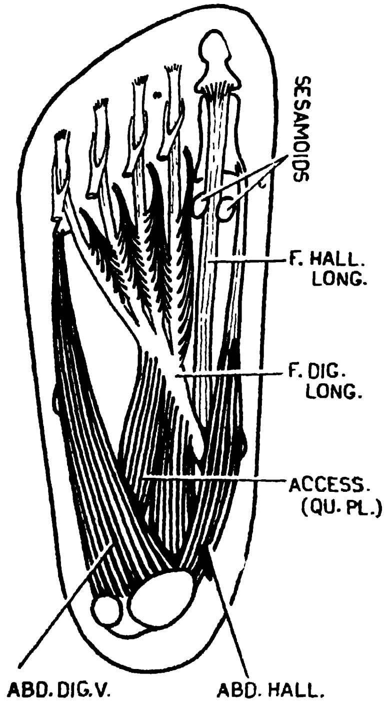


FIG. 454. The second layer of muscles displayed by removal of the Flexor Digitorum Brevis.

The tendon of the *Fl. Digitorum Longus* is the central structure within this frame. It has already been seen crossing superficial to the tendon of the Tibialis Posterior at the back of the medial malleolus; it is now seen appearing from under cover of the Abductor Hallucis and crossing superficially to the tendon of the Fl. Hallucis Longus, abreast of the tuberosity of the navicular bone. It is, then, twice superficial: once when crossing the Tibialis Posterior; again when crossing the Flexor Hallucis Longus. On the under aspect of the proximal phalanges, the four tendinous slips into which the Flexor Digitorum Longus divides pass through rings made by the splitting and decussating of the fibers of the short flexor tendons, and then pass on to be inserted into the distal phalanges.

The Flexor Accessorius (Quadratus Plantae), whose origin will be seen later, approaches the lateral aspect of the common tendon of the Flexor Digitorum Longus from behind, blends with its deep surface, and sends slips beyond it to join the tendons of the Flexor Digitorum Longus to the 2nd and 3rd (and perhaps also the 4th and 5th) toes.

The four *Lumbricales* arise from the tendons of the Flexor Digitorum Longus and are inserted into the dorsal digital expansions. In the hand, the Lumbricales approach the expansions from the radial or thumb side; therefore, in the foot, they approach from the tibial or great toe side. Clearly then, the Lumbricalis to the second toe (or finger) can arise from only one tendon, namely the tendon to the second toe (or finger); the other three Lumbricales have the opportunity of arising in a bipennate manner from the adjacent sides of the tendons to the 2nd and 3rd; 3rd and 4th; 4th and 5th toes (or fingers).

The Flexor Hallucis Longus tendon, beyond the point at which the Flexor Digitorum Longus crosses it superficially, runs along the lower surface of the Flexor Hallucis Brevis, passes onwards between the sesamoid bones developed

in the tendons of insertion of this short flexor, and finally is inserted into the whole breadth of the under surface of the epiphysis of the distal phalanx of the hallux. The Flexor Hallucis Longus, however, also sends fibrous slips to those tendons of the Flexor Digitorum Longus that pass to the 2nd and 3rd digits, or commonly to the tendon that passes to the 2nd digit only. Now, primitively both the Flexor Hallucis and the Flexor Digitorum send slips to each of the five digits (*fig. 455*), but as the primate scale is ascended the muscle arising from the fibula concentrates its attention, apparently for mechanical reasons, on the medial side of the foot, whereas the muscle arising from the tibia concentrates on the lateral side. This is the explanation of the strange crossing and variable connections of the long digital flexors. The slips can best be seen after dividing the Flexor Accessorius and Flexor Digitorum Longus far back and throwing them forwards.

Of the muscles of this second layer, the Flexor Accessorius is wholly inserted into; the Lumbricales wholly arise from; and the Flexor Hallucis Longus is partially inserted into—the Flexor Digitorum Longus.

The Third Layer of Muscles:

(1) Flexor Hallucis Brevis
(2) Flexor Digiti Quinti
(3) Adductor Hallucis Transversus
(form three sides of a square open posteriorly)
(4) Adductor Hallucis Obliquus
(largely fills the square).

The muscles of the third and fourth layers practically confine themselves to the anterior half of the foot. They could be studied in a specimen disarticulated at the tarso-metatarsal joint. In order to obtain access to the 3rd layer, the Flexor Digitorum Longus and the Flexor Accessorius should be divided far back and thrown with the Lumbricales well forwards (*fig. 456*). The base of each of the five metatarsals gives origin to a muscle; that of the 1st to the *Flexor Hallucis Brevis*, those of the 2nd, 3rd, and 4th to the *Adductor Hallucis Obliquus*, and that of the 5th to the *Flexor Digiti Quinti*. [Truly, a few of the fleshy fibers of the last two muscles creep back on to the long plantar ligament,

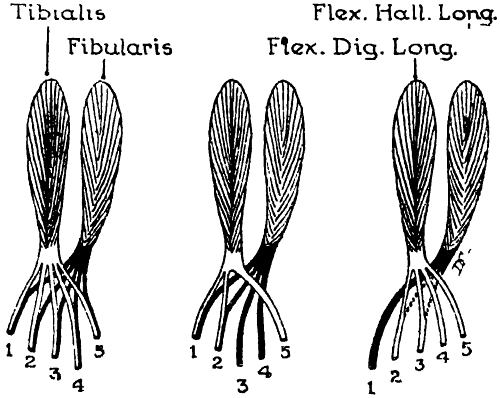


FIG. 455. Scheme explaining the crossing of the long digital flexors. (After Straus.)

which is attached to the bases of 2nd, 3rd, 4th, 5th metatarsals, and, in point of accuracy the Flexor Hallucis Brevis does not arise from the base of its own metatarsal, but by means of two fibrous slips prolonged backwards to the tendon of the Tibialis Posterior and either the 3rd cuneiform or cuboid.] The remaining muscle of this layer, the *Adductor Hallucis Transversus*, is a diminutive structure that springs from the tissues (deep transverse ligs. of the sole) about the heads of the 5, 4, 3 metatarsals.

Insertions. The Flexor Hallucis Brevis splits into two heads of insertion which are attached to the sides of the proximal phalanx of the hallux, and the two sesamoids developed in these heads

play one on each side of the ridge on the under aspect of the head of the first metatarsal. These sesamoids are united to each other by a fibrocartilage, the *plantar* (*accessory*) *ligament*, in which they may be said to be developed. They begin to ossify about the twelfth year (cf. patella which ossifies in 3rd year).

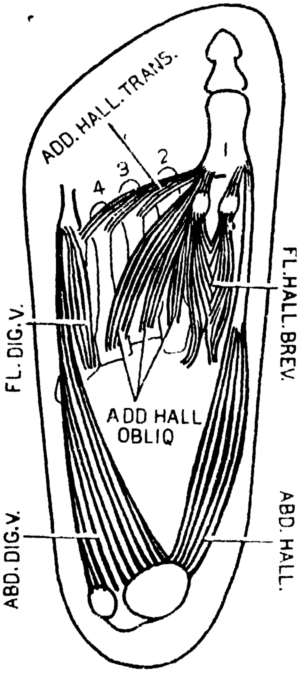


FIG. 456. The third layer of muscles displayed by excision of the Flexor Digitorum Longus and the Accessorius and Lumbricales which are attached to it. The Flexor Hallucis Longus may be left intact.

The medial sesamoid may be in two pieces, an anterior and a posterior—a condition that may be mistaken for a fracture. *The Abductor Hallucis* is inserted in conjunction with the medial head; the *Adductores Hallucis* Obliquus et Transversus with the lateral head. Here is an excellent mechanical device: the two sesamoids together with the fibrocartilage uniting them form a pulley under which the Flexor Hallucis Longus glides. This pulley is, moreover, a moving pulley, the short flexor causing it to be retracted at such times as the long flexor is in action.

The patella, the chief of the sesamoids, is found on an extensor surface. It may be asked *Of what value are sesamoids* to the big toe on a flexor aspect? The answer is "The under aspect of the metatarso-phalangeal joint of the great toe is flexor in name. The joint is, in fact, capable of a greater degree of hyperextension (dorsiflexion) than it is of flexion (plantar flexion) and the sesamoids are only brought into play in overcoming the hyperextension; once this is overcome and flexion initiated, the sesamoids are temporarily functionless".

The Flexor Digiti Quinti is inserted in conjunction with the Abductor Digiti Quinti into the plantar aspect and lateral side of the proximal phalanx of the little toe. The Abductor Digiti V acts on the whole length of the lateral spring of the foot; the Flexor Digiti V acts on its anterior segment; the Abductor Metatarsi V (or the lateral cord of the plantar fascia) acts on its posterior segment.

The Fourth Layer of Muscles:

(1) Seven Interossei.

In order to obtain access to the fourth layer, only one muscle, the Adductor Hallucis Obliquus, need be removed. It will then be appreciated how large this muscle is that fills the hollow of the metatarsal portion of the transverse arch of the foot.

The *Interossei:* Each of the five digits of the foot (as of the hand) is morphologically capable of being abducted and adducted, and ten muscles are required to perform the ten movements. The great toe has its own abductor and adductor and the little toe has its own abductor, accounting for 3 of the 10 required muscles. Seven Interossei perform the remaining 7 movements. When dissect-

ing the dorsum of the foot, an Interosseous was seen to arise in bipennate manner from the adjacent sides of the five metatarsal bones, and to fill each of the four intermetatarsal spaces. These were the 4 Dorsal Interossei; so, by exclusion there are 3 Plantar Interossei. In the hand the Interossei are disposed around the middle finger; in the foot around the second toe. This applies to man and some gorillas; in other primates the Interossei are disposed around the middle finger and middle toe. When at rest the second toe occupies a neutral or axial position—it is at zero, and is fully adducted. The great toe being out of account, the 3 Plantar Interossei are required to adduct or approximate the 5th, 4th, and 3rd toes to the 2nd or axial toe. The dorsal muscle of the first space abducts the 2nd toe medially; that of the 2nd space abducts it laterally. The dorsal muscles of the 3rd and 4th spaces abduct the 3rd and 4th toes laterally.

The dorsal muscles, therefore, abduct from, and the plantar muscles adduct to, a line drawn through the second toe. The plantar muscles are unipennate and arise from the plantar border of the metatarsal of the toe on which they act.

To obtain a full view of the insertions of the Interossei, the Adductor Hallucis Transversus and the deep transverse ligaments of the sole must be severed. Each may then be seen to be attached in part to the side of a proximal phalanx and in part to a dorsal expansion. Their actions are of course more restricted than those of the hand.

Two Long Tendons. The Tibialis Posterior and the Peroneus Longus belong to the ligamentous or deepest layer of the posterior half of the foot. They enter the sole below the summits of their respective springs, i.e., beneath the head of the talus and beneath the cuboid. One being an invertor of the foot, the other an evertor, they must find attachment in front of the transverse tarsal articulation.

The Peroneus Longus enters the sole deep to the Abductor Digiti V, passes obliquely across the sole in the groove on the cuboid which the anterior fibers of the long plantar ligament convert into a canal, crosses the third cuneiform and the backwardly projecting base of the 2nd metatarsal to gain insertion into the lateral side of the base of the first metatarsal and adjacent part of the first cuneiform (*fig. 449*). As the common synovial sheath, that envelops the Peronei Longus et Brevis behind the malleolus, is commonly continuous with the synovial sheath of the Peroneus Longus in the sole, it follows that an injury to either tendon about the ankle may open up a pathway into the sole. In both regions there are well marked mesotendons.

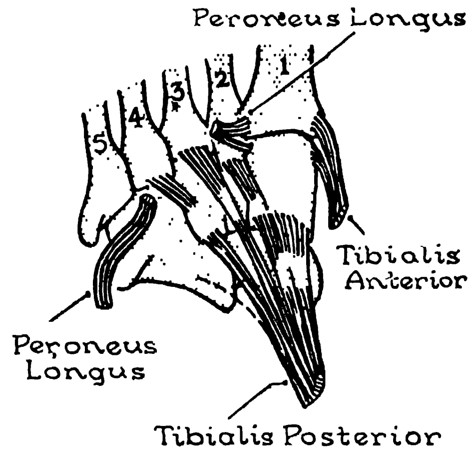


FIG. 457. The grasp of the Tibialis Posterior extends to the small tarsals and to the metatarsals.

The Tibialis Posterior sends two-thirds of its tendon to be inserted into the tuberosity of the navicular and some fibers, passing beyond this, reach the under surface of the first cuneiform. The remain-

ine one-third divides into a number of finger-like bands that pass below the spring ligament and diverge to reach the cuboid, cuneiforms, and the 2nd, 3rd, 4th metatarsal bases. The anterior parts of the finger-like bands are often dissociated, as it were, into a number of phalanges or *plantar ligaments* that lie in line with the Tibialis Posterior tendons and therefore take its pull. The muscle may be said to spread like an open hand to grasp all the small tarsal bones and most of the metatarsals—i.e., the bones anterior to the transverse tarsal joint—and to draw

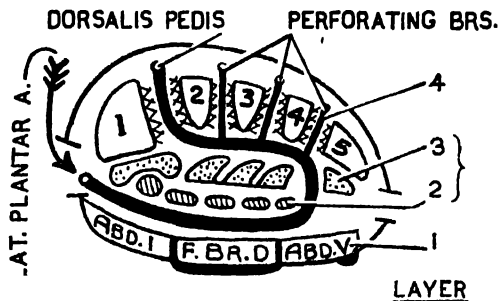


FIG. 458. Scheme to show the lateral plantar artery coursing first between the 1st and 2nd layers of muscles, then between the 3rd and 4th layers.

them medially, backwards, and upwards (*fig. 457*). Its pull criss-crosses that of the Peroneus Longus; so, between them they create the transverse spring of the foot and support the respective longitudinal springs.

The Tibialis Anterior is inserted into the same two bones as the Peroneus Longus, but on their medial side; so, together these two muscles form a stirrup beneath the middle of the sole of the foot (*fig. 504*).

The Vessels and Nerves of the sole can be inserted in figures 452, 454, 456.

The Lateral Plantar Artery (*fig. 460*) is much larger than the medial plantar artery. It is, therefore, the continuation of the posterior tibial artery, in fact if not in name. It appears from under cover of the Abductor Hallucis muscle and, with its companion nerve, runs forwards and laterally between the 1st and 2nd layers of muscles (represented by the Flexor Digitorum Brevis and Flexor Accessorius), and then dipping deeper runs medially between the 3rd and 4th layers (represented by the Adductor Hallucis Obliquus and the Interossei, *fig. 458*). At the hinder end of the third intermetatarsal space it anastomoses with the deep branch of the dorsalis pedis artery and thereby forms a (*deep*) *plantar arterial arch* in precisely the same manner as the

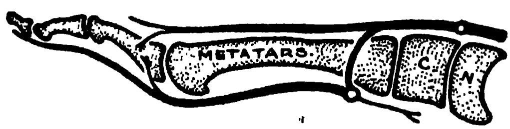


FIG. 459. Scheme of arteries in the anterior part of the foot (compare with fig. 143).

radial artery and the deep branch of the ulnar artery form a deep palmar arch in the hand (*figs. 134, 143*).

The arteries of the anterior half of the foot are arranged in a manner similar to the arteries of the hand (*fig. 459*). There are several anastomotic channels, and the blood stream has the option of flowing through one or more of them. In no case, however, are more than a few channels well developed; hence, the variations in the vessels of these regions.

The deep branch of the dorsalis pedis is but an enlarged posterior perforating artery. The *perforating arteries* spring from the deep plantar arch; so, the arch itself must lie anterior to the bases of the metatarsals, i.e., below the posterior parts of their bodies and therefore below the Interossei also.

The Lateral Plantar Nerve follows its artery closely and sends: (a) cutaneous branches to the lateral 1½ digits, and (b)

motor branches to all the muscles of the sole not supplied by the medial plantar nerve. This includes all seven Interossei and the Adductor Hallucis.

The Medial Plantar Vessels and Nerve of the foot run forwards in the furrow between the Abductor Hallucis and the Flexor Digitorum Brevis. The nerve, like the median nerve of the hand, sends: (a) cutaneous branches to 3½ digits which fan out subjacent to the plantar fascia, and (b) motor branches to a few muscles—the four muscles between which the stem of the nerve runs, namely,

(1) Abductor Hallucis
(2) Flexor Digitorum Brevis
(3) Flexor Hallucis Brevis
(4) Lumbricalis I.

Wherever the nerve sends a branch, there a twig from the artery is also to be found; thus, the digital branches of the nerve are accompanied by digital branches of the artery, which form the ill-developed superficial plantar arch.

Close resemblances, therefore, exist not only between the arteries of the hand and the arteries of the foot, but also between the median and ulnar nerves of the hand and the corresponding medial and lateral plantar nerves of the foot.

The Door of the Foot or "Porta Pedis". (1) Since the lateral and medial plantar vessels and nerves and three tendons enter the sole on the medial side by passing deep to the Abductor Hallucis, this muscle may be thought of as the door or porta of the sole of the foot. (2) The Peroneus Longus enters on the lateral side deep to the Abductor Digiti V, through the back door, so to speak. (3) The perforating vessels enter through the intermetatarsal spaces, as it were, through windows. The Abductor Hallucis is, then, the front door, the main entrance to the foot (*figs. 452, 492*).

Medial Aspect of the Calcaneum. Not until the Abductor Hallucis is reflected and the plantar vessels and nerves are displaced can access to the Flexor Hallucis Longus be obtained where it lies in the groove between the two tubercles of the talus and winds under the sustentaculum tali. Even then the tendon is not seen till the fibrous part of the osseofibrous tunnel in which it is running is

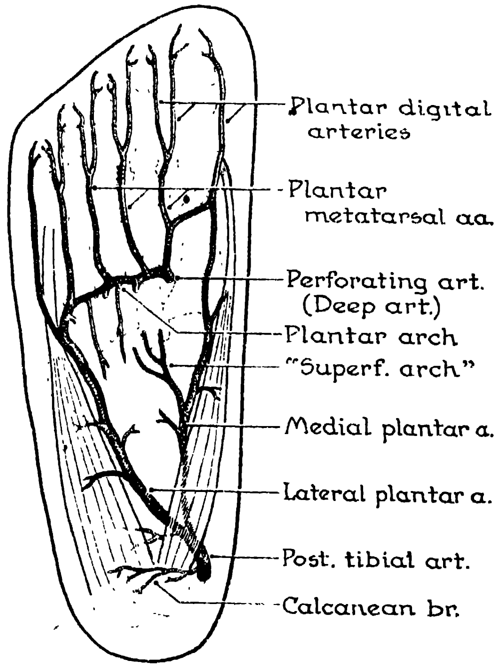


FIG. 460. The plantar arteries.

slit up. The whole of the medial aspect of the calcaneum behind the tendon is overlaid by a soft muscle pad, viz., the medial head of the Flexor Accessorius (Quadratus Plantae) (*fig. 461*). *The Flexor Accessorius* arises from the greater part of the medial surface of the calcaneum in front of the flexor retinaculum and Abductor Hallucis. [A small fibrous lateral head arises from the under surface of the calcaneum just in front of the lateral tubercle.]

Re-arrangement of Tendons. In this

neighborhood the tendons, vessels, and nerves adjust their positions before finally dispersing. Here is a sorting house. On crossing its portals, the various structures pass almost directly to their destinations. It will be remembered that, contrary to expectation, the Flexor Digitorum Longus arises from the tibia, and the Flexor Hallucis Longus from the fibula. The relative positions of the two tendons must, of course, be reversed before their insertions are reached. This is achieved by the Flexor Digitorum Longus crossing the Flexor Hallucis Longus abreast of the tuberosity of the navicular; and it crosses superficially.

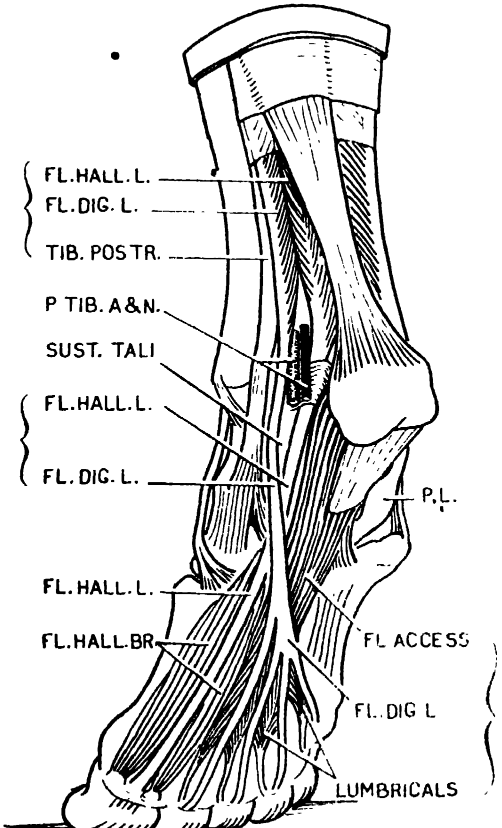


Fig. 461. Structures passing deep to the Abductor Hallucis.

The Tibialis Posterior arises from both tibia and fibula, and, in its endeavor to reach the tuberosity of the navicular (its main site of insertion), it also must cross the Flexor Digitorum Longus. This crossing is effected behind the medial malleolus where the Flexor Digitorum Longus is again superficial. Twice therefore is the Flexor Digitorum Longus superficial, first to the Tibialis Posterior, then to the Flexor Hallucis Longus.

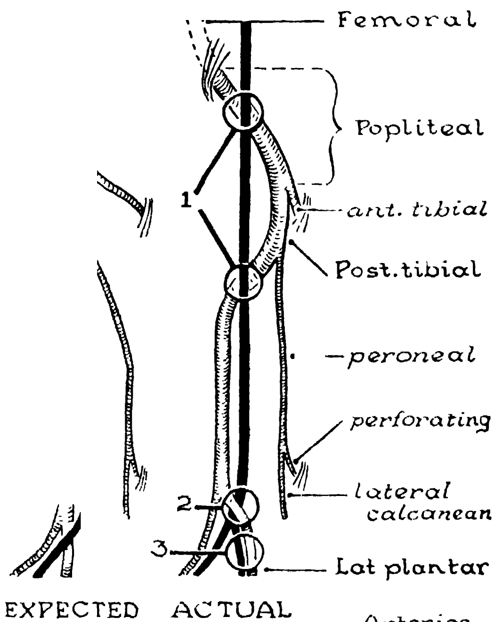


Fig. 462. Unexpected relationships of arteries to nerves

Three Tendons and the Sustenaculum Tali. From its origin to its insertion the *Tibialis Posterior* is never parted from the skeletal plane. After winding round its pulley (the medial malleolus), it must cross the deltoid ligament to reach the tuberosity of the navicular; one third of its tendon passes below the spring ligament, which separates it from the head of the talus, and so it reaches the sole. The *Flexor Digitorum Longus* rubs on the me-

dial side of the sustentaculum tali. The Flexor Hallucis Longus is the only muscle whose tendon actually passes below the sustentaculum tali. Its tendon grooves three bones: the lower end of the tibia, the back of the talus between the medial and posterior tubercles, and the sustentaculum tali. Fibrous bands convert the grooves into an osseo-fibrous tunnel. Finally, it passes between the two sesamoid bones. As the tendon is travelling through the tunnel, the plantar vessels and nerves seize the opportunity to cross it, and so to gain its lateral side where they come to lie on the soft Flexor Accessorius (*fig. 461*).

Comment on Vessels and Nerves. It is helpful to recollect the general rule that *an artery accompanies its companion nerve on the side from which it approaches it.* In the lower limb, arteries mostly approach their companion nerves from the medial side and accompany them on the medial side, e.g., the femoral artery and nerve, the inferior gluteal artery and sciatic nerve, the anterior tibial artery and nerve, and the medial plantar artery and nerve. The rule is broken at three and sometimes four sites in the lower limb, namely, (1) at the back of the knee, (2) at the ankle, (3) in the sole of the foot, and sometimes (4) on the dorsum of the foot (*fig. 462*):

1. If we call the tibial division of the sciatic nerve *the great nerve stem,* and the femoral, popliteal, and posterior tibial arteries *the great arterial stem*, then the great nerve stem pursues a straight course down the back of the limb, whereas the great arterial stem descends on the front of the limb, enters the medial side of the popliteal space, curves laterally towards the neck of the fibula in order "to unload" the anterior tibial artery, an inch further on it "unloads" the peroneal artery, and then re-assumes its proper position on the medial side of the great nerve stem. During this course the great arterial stem describes a bow-shaped curve across the front of the nerve and, so, crosses it twice. While lateral to the nerve it changes its name from popliteal to posterior tibial. So, the popliteal artery is described as crossing the tibial nerve from medial to lateral side, and the posterior tibial artery as crossing the tibial nerve from lateral to medial side, and, on each occasion the artery is rightfully anterior (*fig. 435*).

2. At the ankle the artery and nerve each divide into a medial and a lateral plantar branch. The artery might be expected to remain deep, but it passes superficial to the nerve.

3. The plantar arteries might be expected to lie medial to the corresponding plantar nerves. But this holds for the medial artery and nerve only, because the plantar arteries include the two plantar nerves within their fork (*fig. 490*).

4. On the dorsum of the foot the anterior tibial nerve takes a direct course with the artery on its medial side. Not uncommonly however, the dorsalis pedis zigzags laterally and may cross the nerve once or twice (*fig. 421*).

A List of the Muscles of the Lower Limb

(This list may be found useful in review work.)

Ilio-psoas
  Iliacus
  Psoas Major
Psoas Minor
Gluteus Maximus
Gluteus Medius
Gluteus Minimus
Tensor Fasciae Latae
Piriformis
Obturator Internus
Gemellus Superior
Gemellus Inferior
Quadratus Femoris
Sartorius
Quadriceps Femoris
  Rectus Femoris
  Vastus Lateralis
  Vastus Intermedius
  Vastus Medialis
Articularis Genu
Pectineus
Gracilis
Adductor Longus
Adductor Brevis
Adductor Magnus
Obturator Externus
Biceps Femoris
  long head
  short head
Semitendinosus
Semimembranosus
Tibialis Anterior
Extensor Digitorum Longus
Peroneus Tertius
Extensor Hallucis Longus
Peroneus Brevis
Peroneus Longus
Gastrocnemius
  lateral head
  medial head
Soleus
Plantaris
Popliteus
Tibialis Posterior
Flexor Digitorum Longus
Flexor Hallucis Longus
Extensor Hallucis Brevis
Extensor Digitorum Brevis
Abductor Hallucis
Flexor Hallucis Brevis
Adductor Hallucis
  oblique head
  transverse head
Abductor Digiti Minimi (V)
(Abductor Ossis Metatarsi Quinti)
Flexor Digiti Minimi Brevis
Flexor Digitorum Brevis
Flexor Digitorum Accessorius
Lumbricales
Interossei
  Dorsal
  Plantar

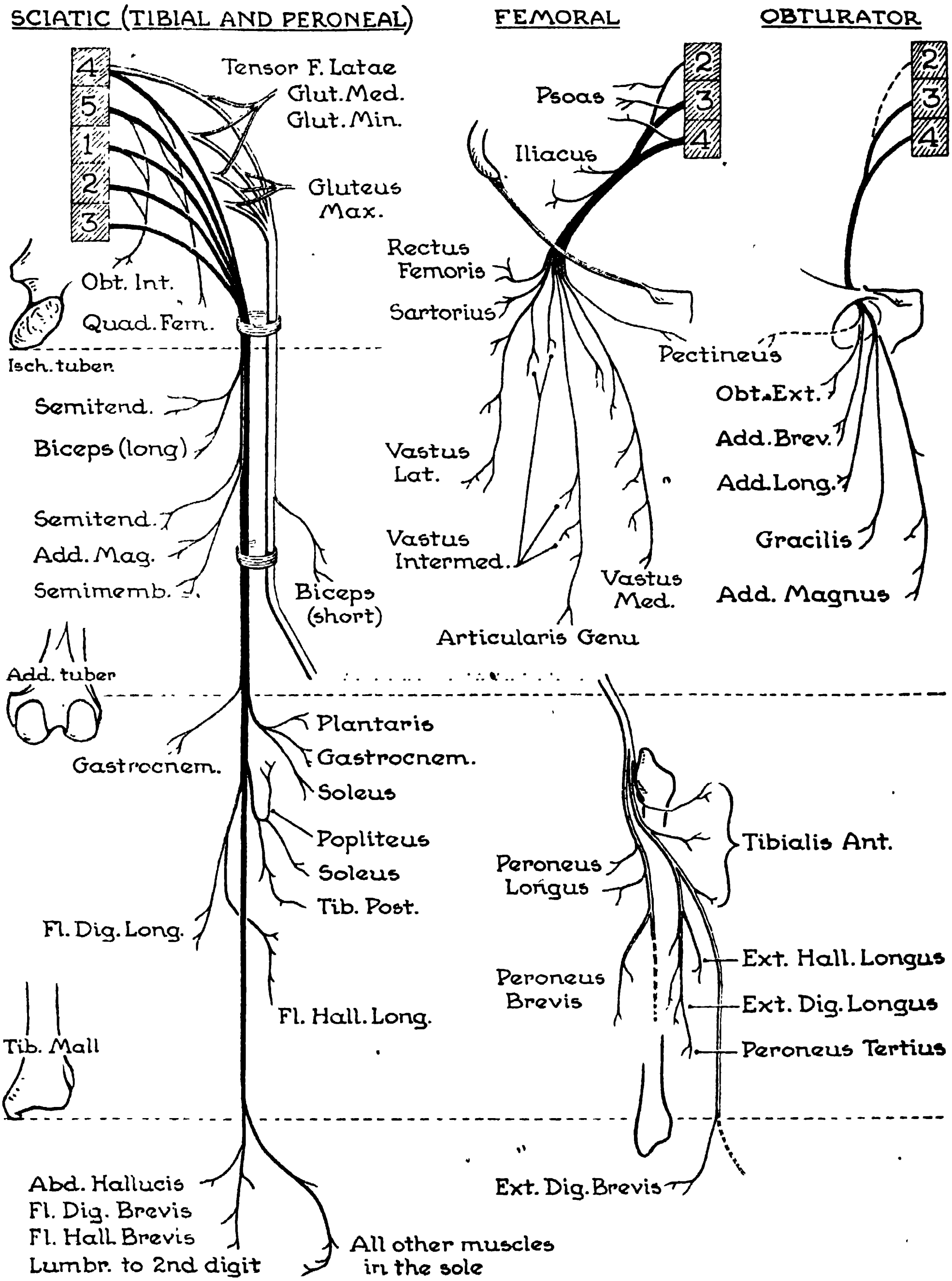


FIG. 463. The motor distribution of the nerves of the lower limb. (You may find it profitable to compare the levels of origin of the branches in the limb you are dissecting with these average levels.)

CHAPTER 16

THE HIP JOINT

The hip joint is a ball and socket joint. The head of the femur is the ball; the acetabulum, deepened by (a) the transverse acetabular ligament and (b) the acetabular labrum form the socket.

The Ball and the Socket. The *head of the femur* forms two-thirds of the sphere, but not of a perfect sphere for it is distinctly flattened above where the acetabulum rests most heavily upon it. It points medially, upwards, and forwards; so, its anterior part is not engaged in the socket when the body is in the anatomical position. The *acetabulum* (acetum, L. = vinegar) or vinegar cup lies at the site of union of ilium, ischium, and pubis. The lowest part of the cup, the part that never rests upon the femur, is deficient and is known as the *acetabular notch.* The remainder of the peripheral part of the cup is horseshoe-shaped; it articulates with the femur and is therefore covered with cartilage. The bottom of the cup, called the *acetabular fossa,* is non-articular, thin, and often translucent. In the bird, the fossa is replaced by a foramen which is closed by a membrane. The acetabular notch is converted into a foramen by a strong ligament, the *transverse acetabular ligament* (*fig. 464*). The acetabulum is deepened by a complete ring of pliable fibrocartilage, the *acetabular labrum,* which is attached to its brim and to the transverse ligament. The labrum grasps the head of the femur beyond its equator and is, of course, concave on its femoral surface.

Epiphyses. The epiphysis of the head of the femur fits like a cap on a spike, and the epiphyseal line encircles the articular margin. It lies entirely within the synovial capsule (*fig. 468*). The ilium, ischium, and pubis each contributes to the articular part of the acetabulum; and the ischium forms the nonarticular part. The epiphyseal plate is triradiate; synostosis is complete by about the 16th year. The line of fusion is detectable in the adult bone, the ilio-pubic eminence being its most conspicuous part (*fig. 329*)

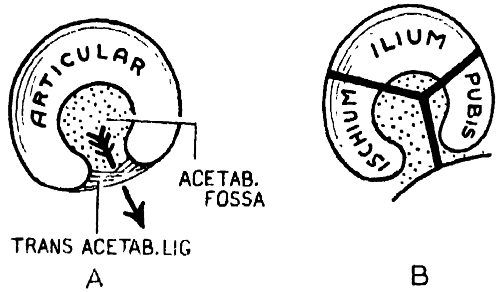


FIG. 464. (A) The acetabulum shown in correct orientation and the transverse acetabular ligament. The arrow passes through the acetabular foramen. (B) The triradiate "epiphyseal" cartilage uniting the pubic, iliac, and ischial parts of the acetabulum.

The Fibrous Capsule and Ligaments. The fibrous capsule is a very strong, thick sleeve. Proximally, it is attached around the brim of the acetabulum and to some extent to the labrum and transverse ligament. Distally, it is attached to the femur along the whole length of the trochanteric line and to a line on the under surface of the neck beside the lesser trochanter, but it is not attached to the femur either posteriorly or above. The fibers run an oblique or spiral course.

If it is assumed that the fibers were originally parallel and took a horizontal

course, then the oblique, spiral or twisted course they take definitively can be attributed to the assumption of the erect posture, which involves extension of the joint. Since the ilium, pubis, and ischium, each take part in the acetabulum, capsular fibers proceed from each of these to the femur; so, ilio-femoral, pubo-femoral, and ischio-femoral ligaments are described.

The Ilio-femoral Ligament (*fig. 465*) (Y-shaped ligament of Bigelow) is a broad, strong band, shaped like an inverted Y. Above, it is attached to the anterior inferior iliac spine and to the acetabular margin for an inch behind the spine; so, it lies deep to the two heads of origin of the Rectis Femoris and is coextensive with them. Below, it creates (with some assistance from the Vastus Medialis) the trochanteric line, which arbitrarily separates the neck from the body of the femur (*fig. 465*).

The Pubo-femoral and *Ischio-femoral Ligaments* are attached to the pubic and ischial parts respectively of the acetabular margin and they pass across the back of the neck of the femur to the tubercle at the upper end of the trochanteric line (*fig. 466*). Some pubo-femoral fibers pass to and create the line below the neck of the femur. *The orbicular zone* is a collection of deep fibers that run circularly and cause an hourglass constriction within the capsule (*fig. 468*).

Sequences. When you stand erect, your line of gravity passes behind the centers of your hip joints. Consequently, your trunk tends to fall backwards, or rather to rotate backwards, the points on which it pivots being the heads of the femora. It is to resist this backward rotation that the anterior part of the capsule is thickened in man and anthropoids to form the ilio-femoral ligament.

In a ball-and-socket joint, which permits free movement in all directions, it is self-evident that the ball must have a larger articular area than the socket.

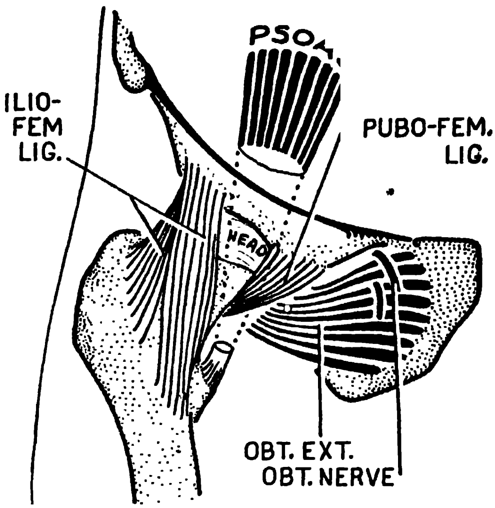


FIG. 465. Capsule of hip joint (from the front). The Psoas guards the weak point.

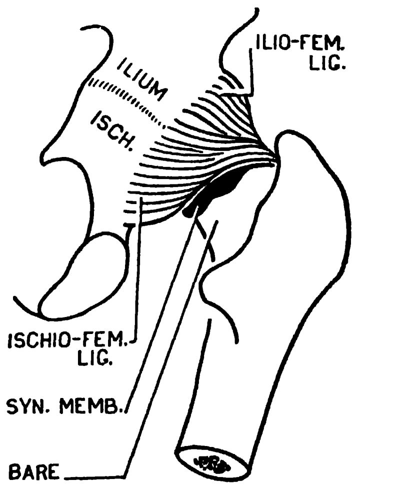


FIG. 466. Capsule of hip joint (from behind).

When you stand erect with toes outturned, the excess of articular cartilage on the ball-like head of the femur is directed forwards. Its lateral part is protected by the ilio-femoral ligament; its medial part by the pubo-femoral ligament; but the

intermediate part, which most requires support, has no covering ligament; indeed, this part of the capsule is commonly perforated. You are not, however, to accuse Nature of constructing a mechanically insecure joint, because playing across this critical area is the **tendon of the Psoas.** A tendon is something better than a ligament—a ligament is a passive structure; whereas a tendon, in virtue of the muscle at its proximal end, is under control; it is active and alert.

If you appreciate the beauty of this device, you will be able to place the psoas

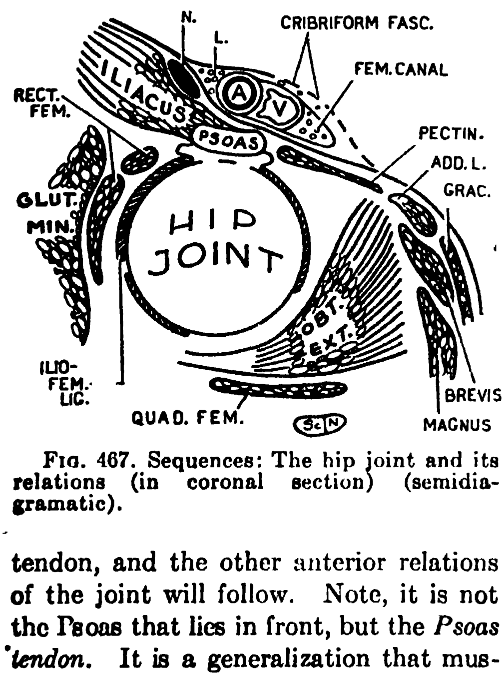


FIG. 467. Sequences: The hip joint and its relations (in coronal section) (semidiagramatic).

tendon, and the other anterior relations of the joint will follow. Note, it is not the Psoas that lies in front, but the *Psoas tendon.* It is a generalization that muscle fibers are unable to survive the pressure produced by such unyielding structures as bone, cartilage, or ligament and therefore they give place to tendon. Employing this generalization, you might infer that the Psoas must here be tendinous. Tendons at such locations require bursae to diminish friction and to facilitate free play. To this generalization the Psoas tendon is no exception; hence, the *Psoas bursa* which commonly communicates with the joint between the iliofemoral and pubo-femoral ligaments (*fig. 467*). Powerful tendons make their mark: in this case the mark is the lesser trochanter of the femur. In front of the tendon lies the femoral artery. Now, the tendon is not as wide as a finger; so, if the femoral artery is in front, there is clearly no room for anything else. Hence, the femoral vein and nerve must lie in front of other structures. The nerve, which is lateral, is in front of the Iliacus; the vein and lymph vessels, which are medial, are in front of the Pectineus. These are but names, and you can neither dissect names nor operate upon them. The desired information is this: the nerve is separated from the joint by the thickness of the fleshy Ilacus, the artery by the toughness of the Psoas tendon, the vein by the thinness of the fleshy Pectineus.

Synovial Membrane lines all parts of the interior of the hip joint save where there is either articular cartilage or fibrocartilage. It is so with all synovial joints. The membrane lines the neck of the femur completely in front, and as far as the Obturator Externus tendon behind, and it stretches across the acetabular fossa.

Note the following details—before opening the joint: (a) the Psoas bursa communicates with the hip joint rarely in the young, but commonly in the adult (20% of 478 limbs, aged 20–92 years). (b) The synovial membrane protrudes posteriorly between the free lower border of the fibrous capsule and the neck of the femur—just as at the elbow it protrudes between the annular ligament and the neck of the radius—and acts as a bursa for the Obturator Externus tendon (*fig. 466*). So, an incision or puncture made above the tendon will certainly enter the

joint; one made below will almost certainly miss it, for here the neck is bare or extra-articular. (c) The fat in the obturator region sends a prolongation under the transverse ligament into the acetabular fossa where it forms an extra-synovial pad (Haversian gland) of fat, or rather a collection of oil, fat being fluid at body temperature. On flexing an exposed joint, you can see fat being sucked in with the purpose of avoiding the formation of a vacuum (*fig. 468*).

Note—after opening the joint: (d) The synovial membrane around the neck is raised into several loose longitudinal folds, *retinacula* (cervical ligaments), in which arteries ascent to the head and supply the whole head (Chandler). (e) Within the joint there is a conical tube of synovial membrane. This tube is situated between the head of the femur and the acetabular fossa; so, it is flattened and triangular. In fact, it resembles a flattened megaphone. The femoral surface is concave; the acetabular surface is convex; both margins are free; the apex is attached to the pit or fovea near the centre of the articular surface of the head; the femoral side of its base is reflected on to the transverse ligament; the acetabular side of its base is continuous with the sheet of synovial membrane that covers the fat pad in the acetabular fossa—this sheet is attached to the articular margins of the fossa. (f) The synovial tube transmits blood vessels to the head of the femur, and it surrounds a fibrous band, called the *ligament of the head* (lig. teres), which connects the head to the transverse ligament and to the lips of the acetabular notch. The acetabular notch is situated inferiorly; so, it follows that the ligament ascends and that it becomes taut on adduction, as when the knees are crossed. (g) It is evident that a probe, pushed through the acetabular foramen, would pass extra-synovially either (a) into the acetabular fossa, or (b) through the synovial tube to the head of the femur. Branches of the medial femoral circumflex and obturator arteries follow both courses.

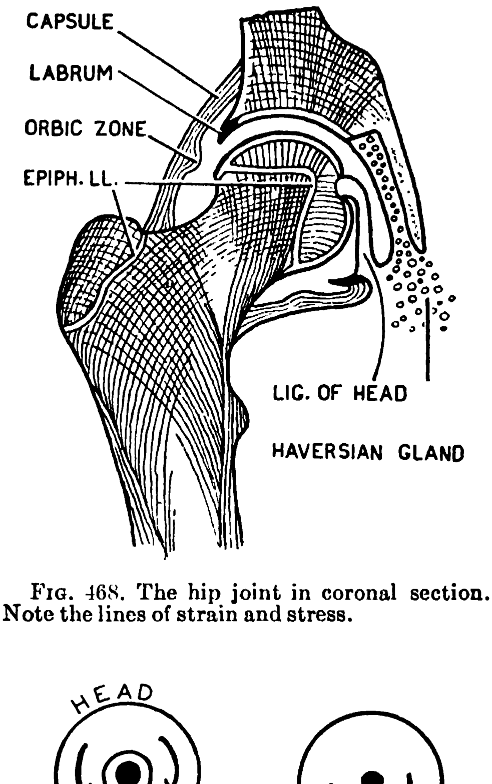


FIG. 468. The hip joint in coronal section. Note the lines of strain and stress.

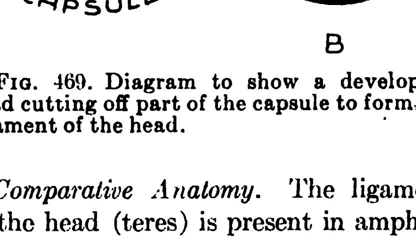


FIG. 469. Diagram to show a developing head cutting off part of the capsule to form the ligament of the head.

Comparative Anatomy. The ligament of the head (teres) is present in amphibians and reptiles with limbs, in birds, and in most mammals. It is absent however in some, e.g., the elephant, rhinoceros, seal, sloth, and the orang. It is regarded

as a pinched off part of the capsule or perhaps of the Pectineus (*fig. 469*).

Observations. (1) When you stand erect or bend forwards over a basin, your ankle and knee joints are locked, and your foot, leg, and thigh bones become temporarily a rigid unit (*fig 470*). A side force then applied to the foot is greatly amplified at the upper end of the femur—as at the end of a long screw driver— and may possibly result in fracture of the neck of the femur. You can satisfy yourself of this, if you grasp the femur of the cadaver while you manipulate the foot of the locked limb. (2) When the ankle joint is plantar-flexed (toes pointed) and the

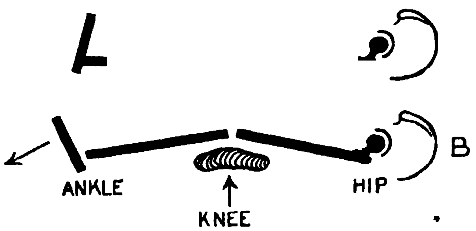


FIG. 470. The lower limb, (A) rigid, (B) flail, due to pillow placed under knee.

knee flexed, some degree of rotation is allowed at these joints and the rigidity is lost. (3) A pillow placed under your knee, when you lie down, automatically results in flexion of the hip, knee, and ankle. (4) The posture conducive to dislocation of the hip joint is one in which the joint is fully flexed and medially rotated; as on bending forwards with toes turned in. Flexion brings the shallow part of the acetabulum to rest on the femur; medial rotation brings the head of the femur to the back. A weight (such as a sack of potatoes) then falling on the back will dislocate the head of the femur on to the dorsum ilii. The ligament of the head (lig. teres) is torn in the process. (5) The security of the hip joint depends upon the depth of the socket, the strength of the ligaments (especially the ilio-femoral), and on the Ilio-psoas and the short muscles.

Relations. *Anteriorly*—Psoas and femoral artery, Iliacus and femoral nerve, Pectineus and femoral vein (*fig. 467*). *Laterally.*—Rectus Femoris in front of ilio-femoral ligament (p. 387), and Gluteus Minimus. *Inferiorly*—The Obturator Externus crosses below the head and runs behind the neck. *Posteriorly*—Piriformis, Obturator Internus and Gemelli, upper border of Quadratus Femoris, and the sciatic nerve. The relationship of the sciatic nerve is appreciated only when the obliquity of the acetabular margin is kept in mind (*fig. 394*)

Blood and Nerve Supply. *Arteries*—obturator, medial femoral circumflex, lateral femoral circumflex, and gluteal.

The head of the femur receives 3 sets of arteries: (a) The never-failing and main set of three or four arteries that ascends in the synovial retinacula on the postero-superior and postero-inferior parts of the neck, perforate the neck just distal to the head, and bend at 45° towards the centre of the head where they anastomost freely with (b) terminal branches of the nutrient artery of the shaft, and in 80 per cent of instances with (c) the artery of the lig. of the head (lig. teres). This last artery does not enter the head until the centre of ossification (*fig. 13*) has extended to the fovea for the lig. of the head, i.e., about the 12th to 14th year. This anastomosis persists even in those of advanced age; but in 20 per cent it does not establish itself. (Wolcott.)

Nerves—femoral n. (via nerve to Rectus Femoris), *sciatic n.* (via nerve to Quadratus Femoris), and *obturator n.* (anterior division).

Movements. The movements permitted are circumduction and rotation. *Hyperextension* is prevented by the ilio-

femoral ligament. *Flexion* is arrested by the hams, when the knee is extended, and by the thigh coming into contact with the abdominal wall, when the knee is bent and the hams thereby relaxed. *Medial rotation* winds up the spirally running fibers of the capsule and, so, is self-arresting; *lateral rotation* unwinds them and is more free. The ligament of the head is taut in adduction.

and Adductor Longus may possess is one of medial rotation, because they are inserted lateral to the axis (*fig. 471*). It is a mistake, obviously, to suppose that the axis passes through the greater trochanter and through the shaft of the bone.

To understand the actions of the abductors and medial rotators, the pelvis and femur must be held in correct orientation;

TABLE 17

Muscles Acting on the Hip Joint

CIRCUMDUCTORS

Flexors	Extensors	Abductors	Adductors
Ilio-psoas	Gluteus Maximus	Gluteus Medius	Adductor Magnus
Rectus Femoris	The 3 hams	Gluteus Minimus	Adductor Brevis
Sartorius	Adductor Magnus (Ham part)	Tensor Fasciae Latae	Adductor Longus
Pectineus		Piriformis	Pectineus
Adductor Longus		Sartorius	Gluteus Maximus
Adductor Brevis			Short Muscles
Adductor Magnus (Obt. part)			Obturator Internus
Tensor Fasciae Latae			Gemelli
			Obturator Externus
			Quadratus Femoris

ROTATORS

Medial	Lateral
Gluteus Medius	Gluteus Maximus
Gluteus Minimus	Short Muscles
Tensor Fasciae Latae	Piriformis
	Obturator Internus
	Gemelli
Adductor Magnus (Ham part)	Obturator Externus
	Quadratus Femoris
	Ilio-psoas
With foot on ground:	Pectineus
Ilio-psoas	Upper adductor mass
Pectineus	
Upper adductor mass	

Table 17 shows that *abduction* and *medial rotation* are practically controlled by the 3 muscles supplied by the superior gluteal nerve; and that adduction and lateral rotation involve similar groups of muscles.

When the foot is on the ground, rotation of the femur takes place around an axis passing through its head and intercondylar notch. This being so, any rotatory power the Ilio-psoas, Pectineus,

that is, the anterior superior spines and the upper end of the symphysis lie on the same coronal plane and the head of the femur is directed forwards as well as medially and upwards, i.e., the greater trochanter lies behind the plane of the head. The *function of the abductors* is to prevent the pelvis from becoming adducted, that is, to prevent the body from falling to the opposite side when only one leg is on the ground, as in walking. The

function of the medial rotators **is to rotate the pelvis** laterally and therefore by **advancing** the opposite leg (the leg off the **ground**) to increase the stride in walking.

The *Gluteus Maximus* is hardly required in walking because this is essentially a movement for flexors, and the hams suffice, but the Gluteus Maximus

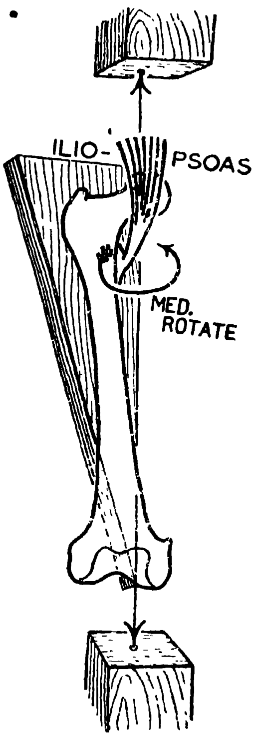


FIG. 471. Explaining the action of the Psoas and Upper Adductors as medial rotators of the hip joint when the leg is fixed

is necessary to climbing stairs, jumping, and running.

THE KNEE JOINT

General Observations. It is apparent that the chief movements occurring at the knee joint are *flexion* and *extension* and that the joint is of the hinge variety. That some degree of *axial rotation* is also permitted you can easily satisfy yourself by the following procedure: Sit on a table with your legs dangling over the side, and rotate your foot as far medially and then as far laterally as it will go. While doing so, apply the fingers of both hands to the sides of the joint and you will feel the tibia rotate medially and laterally on the femur. Rotation, then, is permitted while the knee is in the position of flexion and semi-flexion. Later you will see that a slight degree of medial rotation of the femur is necessary to the completion of the act of extension. So, the joint is a modified hinge or ginglymus joint.

When standing up and leaning forwards, as when washing your face, you can *move your patella from side to side* because the Quadriceps Femoris is relaxed. At one time or another when standing up each of us has received, perhaps in play, an unexpected blow on the back of the knee with the result that the joint gave way, nearly causing us to fall; clearly because the Quadriceps, not being in action, was caught unawares. The Quadriceps is not required to be in action when we stand erect, because the line of gravity passes in front of the axis of the knee joint. A considerable economy in muscular effort is effected thereby.

When the knee is extended (as when sitting on a chair with heels resting on another chair), *the skin in front of the patella* is loose and can be picked up between the fingers and thumb, just as, and for the same reason as, the skin behind the olecranon process of the ulna can be picked up when the elbow is extended. When, however, the knee and elbow are flexed, the slackness is taken up and there is no longer any redundant skin. At both sites a bursa (prepatellar and olecranon), interposed between the skin and bone, permits this free movement of the skin. The precise depth of the ***pre-patellar bursa*** varies; it may be

either in the subcutaneous areolar tissue, or deep to the fascia lata, or actually in the substance of those fibers of the Quadriceps tendon that pass across the front of the patella. According to the depth at which it lies buried in connective tissue, it is referred to as the *subcutaneous, subfascial,* or *subtendinous prepatellar bursa.* Commonly, two bursae are present, one in front of the other, with the intervening partition largely broken down. Strands of fibers remain as evidence of the double origin.

If you kneel on a piece of inked paper, you will find on rising that your skin is marked over the tibial tubercle, ligamentum patellae, and apex of the patella, indicating them to be the bearing surface. Here, in front of the ligamentum patellae, is another bursa, the *superficial infrapatellar bursa.* If you kneel again and stretch forwards, as a housemaid might when washing a floor, you will find that the skin in front of the patella and prepatellar bursa is marked.

To call the ligamentum patellae a "*ligament*" is in a sense taking a liberty with a term. The ligament, truly, unites two bones, the tibia and the patella. The patella, however, is but an ossific nodule or sesamoid bone developed on the deep surface of the tendon of the Quadriceps Femoris where it plays upon the lower end of the femur; the ligament is but the distal end of this tendon.

Divisions of the Joint. The bones taking part in the knee joint are: the femur, the tibia, and the patella; the fibula is only indirectly associated. Primitively, there were *three joint cavities* now merged into one. One is situated between the medial condyles of the femur and tibia; one between the lateral condyles of the femur and tibia; and one between the patella and the femur. They may be referred to as the medial and lateral condylar articulations and the patellar articulation. The condylar articulations are partly subdivided by medial and lateral menisci or semilunar fibro-cartilages into upper and lower parts.

The Patella and the Patellar Articulation

As one stands erect with feet together and toes pointing forwards (the anatomical position), the balls of the big toes, the medial malleoli, and the knees of the two sides are in contact with each other, and the tibiae of the two sides are parallel. Not so the femora; they are set obliquely; and, though they are in contact at the knees, they are separated above by the width of the pelvis. There is, accordingly, an open angle at the lateral side of the knee, comparable to the angle at the side of the elbow, towards which the patella tends to become dislodged when the Quadriceps contracts; and, because the pelvis is relatively wider in the female than in the male and the femur shorter, the angle is more acute and, therefore, the tendency to dislocation is greater in the female than in the male. Dislocations are, however, not common. Why, it may be asked, are they not universal? Largely because of two factors:

1. The forward projection of the lateral condyle of the femur.
2. The low attachment of the Vastus Medialis to the patella.

The first is a bony mechanism: The front of the lower articular end of the femur is a pulley or trochlea in which the patella glides. Now, the lateral bank of this trochlea is deep—much deeper than the medial (*fig. 472*). From this it follows that the posterior aspect of the patella is, as the counterpart of this trochlea, divided into two areas, of which the postero-lateral is larger than the

postero-medial. Hence, a patella falls to the side to which it belongs when it is placed on a table with its articular surface down and its apex pointing away from the observer—a right bone will fall to the right; a left bone to the left. It falls, of course, to its larger and more heavily weighted side.

The second is a muscular mechanism: The Rectus Femoris and the Vastus

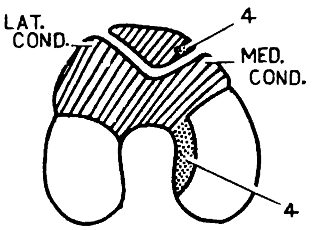


FIG. 472. The patella in its trochlea.

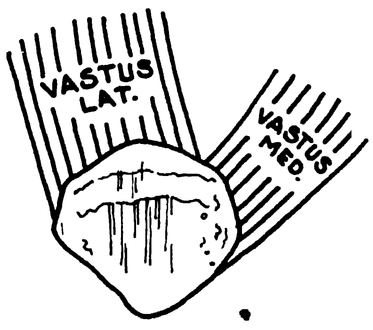


FIG. 473. The patellar attachments of the Vasti Medialis and Lateralis.

Intermedius are attached to the upper border or base of the patella, and on contracting they pull obliquely upwards in the line of the femur. The Vastus Medialis and Vastus Lateralis are continuous with each other at their patellar attachments and they occupy the plane between the Rectus Femoris and Vastus Intermedius. The Medialis is attached to the upper $\frac{2}{3}$ of the medial border of the patella and only slightly to the upper border; the Lateralis is attached to almost the whole length of the upper border and only slightly to the lateral border (*fig. 473*). The Medialis, therefore, derives a lower origin from the epicondylar line and intermuscular septum than the Lateralis. Hence, the lower fibers of the Medialis draw the patella medially; those of the Lateralis draw it upwards but without a lateral pull. The Medialis, therefore, actively prevents lateral displacement of the patella; the lateral condyle of the femur does so passively.

You can demonstrate this by bringing the relaxed Quadriceps into action, e.g., while sitting down with knee extended, raise the heel from the ground and follow

FIG. 474. The three paired facets on the posterior surface of the patella articulate with the femur as shown in figure 475. The medial vertical facet (4) articulates along the margin of the intercondylar notch during full flexion (see fig. 472).

the movements of the patella and ligamentum patellae.

A transverse incision opening into the knee joint above the patella incises successively: skin, fat, fascia lata, Rectus tendon, tendons of the Vasti Lateralis et Medialis, tendon of Vastus Intermedius, and the synovial capsule of the joint. These make a rather bewildering array of fibrous laminae when seen for the first time.

The posterior aspect of the patella has two lower, two intermediate, and two upper facets, in addition to a medial vertical facet (*fig. 474*). These articulate in turn during extension, slight flexion, flexion, and full flexion (*fig. 475*). The human patella would be less liable to

fracture if it possessed a single concave facet the whole of which was continuously in articulation with the femur, as it is in lower mammals (*fig. 476*).

PALPATION. A considerable amount of the articular surface of the knee joint can be palpated. When the Quadriceps is relaxed (heel on chair position), push the patella first medially and then laterally and learn how much of its articular (posterior) surface is palpable. When the knee is bent, you can easily feel the anterior parts of the margin of the upper aspect of the tibia, and you can trace the margin of the trochlea or patellar surface of the femur. As the knee moves gradually from the extended to the fully flexed position, you can feel the patella glide laterally on to the under aspect of the lateral condyle of the femur and leave the trochlea and the entire under aspect of the medial condyle exposed, except for a strip bounding the medial border of the intercondylar notch (*fig. 472*). This strip is in articulation with a vertical facet on the most medial part of the posterior surface of the patella (*see areas 4 in figs. 472, 474*).

The Functions of the Patella. Experimental work has shown that when the knee joint is flexed, the patella is a mechanical hindrance to extension. Indeed, the removal or excision of the patella results in increased efficiency—but in the later degrees of extension (say 150°–180°) the patella improves the efficiency by holding the patellar tendon away from the axis and thereby increasing the extending momentum of the Quadriceps pull. (H. Haxton, *fig. 477*).

The Tibio-femoral or "Condylar" Articulations. On the upper surface of each tibial condyle there is an oval articular area for the corresponding femoral condyle. The articular areas are separated from each other by a narrow nonarticular area, which widens in front into a triangular area, and behind into a square area, called the *anterior* and *posterior intercondylar areas* (*fig. 484*).

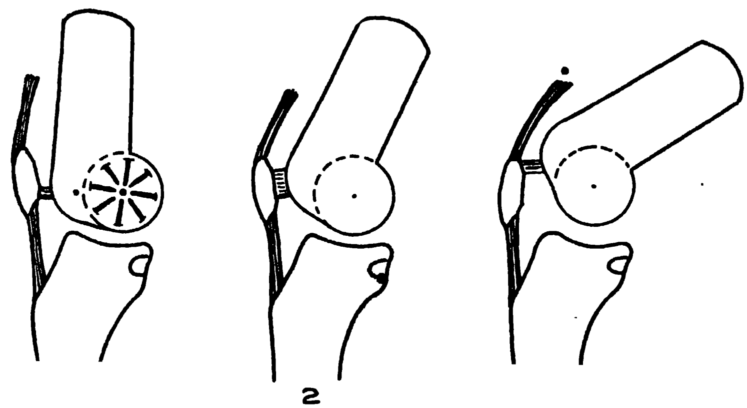


FIG. 475. The knee joint during (1) extension, (2) slight flexion, (3) flexion (see fig. 474). At the hub of the wheel, or centre of the disc, lies the epicondyle.

COLLATERAL LIGAMENTS. Were the femoral condyles round and their collateral ligaments arranged as in figure 478, the joint could be flexed both forwards and backwards, because the ligaments would be equally taut in all positions. But these circumstances do not obtain. For, (a) the medial and lateral femoral condyles project backwards like discs or wheels; (b) the collateral ligaments are

attached above not to the centers of the condyles but to the epicondyles which project like hubs from the centers of the superadded wheels; and (c) below they are attached far back——the medial (tibial collateral) ligament to the medial surface of the tibia adjacent to its medial

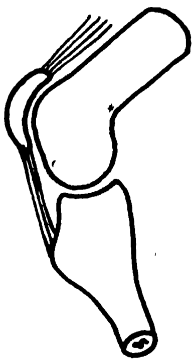


FIG. 476. Knee joint of a sheep showing a single concave facet on the patella.

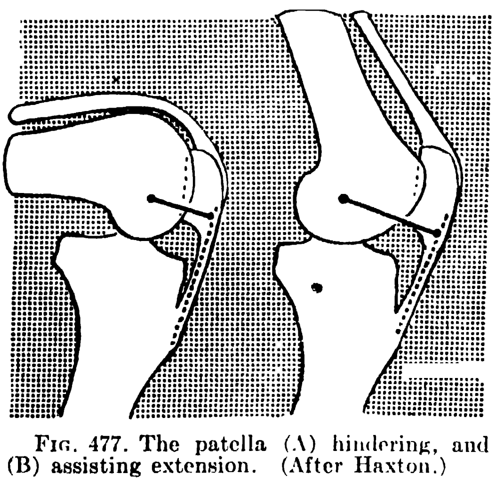


FIG. 477. The patella (A) hindering, and (B) assisting extension. (After Haxton.)

border; the lateral (fibular collateral) ligament to the head of the fibula just in front of its apex (*figs. 479, 480*). What significance have these eccentric attachments? When the knee is flexed, the collateral ligaments are slack and permit of medial and lateral rotation. When the knee is extended, they are taut and, so, help to prevent hyperextension.

Anyone appreciating these points will have no trouble in running his finger along the course of the collateral ligaments and of deciding if they are tender and sprained.

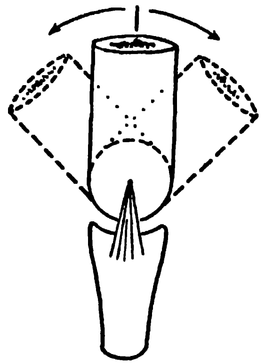


FIG. 478. The hypothetical tibio-femoral joint, as a perfect hinge.

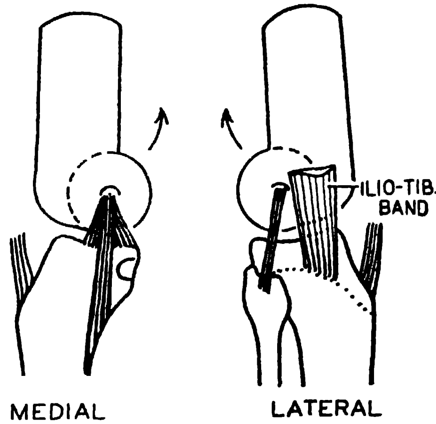


FIG. 479. Because of their eccentric attachments the collateral ligaments are taut during extension. The insertion of the ilio-tibial band or tract is in front of the transverse axis of the joint and therefore helps to keep the extended joint extended.

The Medial (tibial collateral) Ligament has a superficial and a deep part. The superficial part, just described, is a long band that bridges the groove on the tibial condyle where the Semimembranosus is inserted, and the hollow below the condyle in which the medial inferior

genicular vessels and nerve run (*fig. 482*). This band is crossed by 3 tendons—Sartorius, Gracilis, and Semitendinosus—each of which is controlled by a different nerve, and a bursa intervenes.

The deep part is deltoid and is attached to the margin of the tibial condyle.

One or more *bursae* lie deep to the long band and help it to slide backwards and forwards on the deep part of the ligament and on the tibial condyle.

The Lateral (fibular collateral) Ligament is a round cord that extends from the lateral epicondyle to the margin of the head of the fibula in front of its apex. This cord is crossed by 1 tendon—the Biceps tendon—a bursa intervening.

(a) The superficial band of the medial ligament may be regarded as the downward continuation of the sciatic part of the Adductor Magnus. It is directed downwards and forwards. (b) The lateral ligament is regarded as the upward continuation of the Peroneus Longus. It is directed downwards and backwards. Functionally, both ligaments restrict lateral rotation of the leg when the foot is off the ground, and medial rotation of the femur when the foot is on the ground.

THE HEAD OF THE FIBULA is situated far back. Lay an articulated tibia and fibula on the table and note that the back of the medial condyle of the tibia and the head of the fibula touch the table, and that between them there is a gutter in which the Popliteus plays. So, to palpate the head of your own fibula, place your fingers behind your knee and carry them forwards round its lateral side.

Sequences. The upper end of the tibia and fibula may arbitrarily be fitted into *an oblong frame* in which the head of the fibula occupies the postero-lateral angle (*fig. 481*). From a consideration of this fact the following sequences might reasonably be surmised:

1. The lateral condyle of the tibia is shorter from before backwards than the

FIG. 480. The collateral ligaments are slack during flexion and permit rotation.

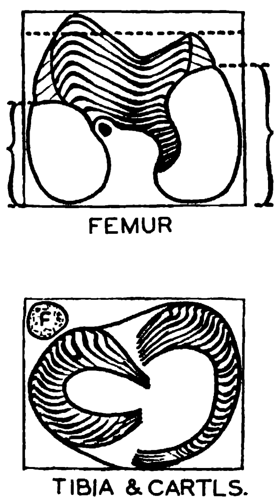


FIG. 481. (A) The upper ends of the tibia and fibula in an oblong frame: Sequences. (B) The lower articular aspect of the femur: Sequences (see text).

medial condyle by approximately the thickness of the head of the fibula.

2. Therefore, of the two semilunar fibro-cartilages or menisci that rest on and fit the tibial condyles and are bound to their margins by *coronary ligaments*, the lateral is shorter than the medial.

The shorter lateral semilunar is shaped like a small "o", the longer medial semilunar like a capital "C". The ligamentous ends of the "o" are attached to the nonarticular part of the upper surface of the tibia close together; the ligamentous ends of the "C" are attached far apart, embracing those of the "o".

3. Therefore, the portion of the lateral condyle of the femur that articulates with the lateral condyle of the tibia (and its semilunar) is shorter antero-posteriorly than the corresponding part of the medial condyle of the femur. [Note, the condyles of the femur have patellar and tibio-semilunar areas. Just now reference is to the tibio-semilunar areas.]

4. Therefore, as the joint passes from full flexion to full extension, the medial condyle of the femur has farther to travel than the lateral condyle.

5. During extension the two femoral condyles rotate on the tibia and its semilunars as do the two rear wheels of a vehicle on a road, —— millimeter for millimeter and inch for inch. Therefore, when the shorter lateral femoral condyle has run its course, the longer medial condyle has still a certain distance ($\frac{1}{2}$ inch) to run.

6. During extension the revolving lateral femoral condyle is arrested by two mechanical obstacles. Both leave their mark on it. One, the anterior margin of the lateral semilunar creates and fits into the curved groove running from the anterior part of the intercondylar notch to the lateral margin of the condyle; the other, the taut anterior cruciate ligament, creates and fits into the subsidiary notch at the antero-lateral part of the intercondylar notch.

7. The Quadriceps Femoris, however, continues to contract with the result that, while the medial femoral condyle is completing its course ($\frac{1}{2}$ inch), the femur is rotating medially on its long axis, the pivot around which it turns being the anterior cruciate ligament.

8. At the same time the lateral femoral condyle and the lateral semilunar, whose sharp anterior margin is locked in the groove on the lateral femoral condyle, slide forwards together on the tibia, moving as one structure.

It is a matter of interest and significance that the posterior end of the lateral semilunar is attached to the femur by an oblique band that passes either in front of (lig. of Humphry) or behind (lig. of Wrisberg) the posterior cruciate ligament. In most animals this oblique band is the sole posterior attachment of the lateral semilunar. This indicates that its allegiance is to the femur rather than to the tibia.

9. The upper surface of the lateral tibial condyle is, therefore, flat to allow of this forward gliding; and the lateral semilunar is broad and expansive in order to act as a carriage or toboggan for the lateral femoral condyle.

10. The upper aspect of the medial tibial condyle is concave to allow of flexion, extension, and rotation. And its semilunar, which does not act particularly as a carriage for the medial femoral condyle, is narrow. In front it is tapering.

11. The medial femoral condyle is, then, completing the process of extension at the same time as the femur is undergoing axial rotation. No special rotator muscles are provided; the Quadriceps Femoris, acting against the obstruction offered by the anterior cruciate ligament, is alone responsible. When these movements are completed, the anterior border of the medial semilunar fits into a curved groove on the medial femoral condyle.

12. The lateral (fibular collateral) ligament passes to the lateral margin of the head of the fibula and, therefore, lies wide

of the lateral tibial condyle, and therefore wide of the lateral semilunar. In fact, the space between them is wide enough to afford a passage for the tendon of the Popliteus (*fig. 482*).

13. But with the medial (tibial collateral) ligament it is different: its deeper deltoid part is attached to the margin of the medial condyle of the tibia, and therefore does come into contact with the medial semilunar and blends with it.

The anterior cruciate ligament has been seen to occupy, during extension, a small subsidiary notch at the anterolateral part of the intercondylar notch of the femur. The presence of this subsidiary notch in the dried femur affords evidence that the particular knee joint was capable of being fully extended, and therefore that its owner walked erect. The femora of certain prehistoric men, such as Java Man (Pithecanthropus Erectus) and Rhodesian Man present such well-marked notches for the anterior cruciate ligament that they unquestionably are entitled to the term "Erectus"; but the term would be ill-applied to Neanderthal Man whose femora have no suggestion of a notch. For this and other reasons, it is believed that his was a crouching gait.

The Intercondylar Septum *figs.* (*483, 484*). In prenatal life a vertical septum or partition separates the medial and lateral condylar joints from each other. The lower border of this septum is attached to the intercondylar area on the upper aspect of the tibia. The posterior half of its upper border is attached to the intercondylar notch of the femur; the anterior half is free and extends from the intercondylar notch of the femur to the patella just below its articular surface. So, it is possible—theoretically at least—to pass a needle from the front of the joint to the back without entering the synovial cavity, the needle remaining within the intercondylar septum. A perforation usually appears in the septum (*fig. 484*): occasionally it is pinpoint in

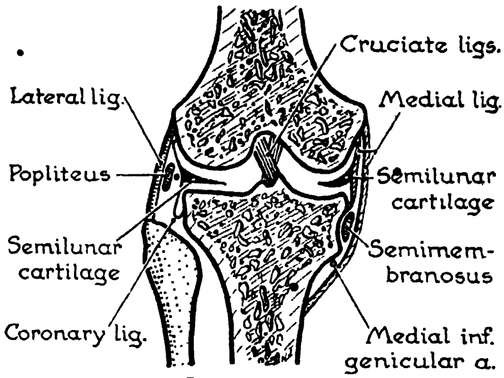


FIG. 482. The knee joint, in coronal section.

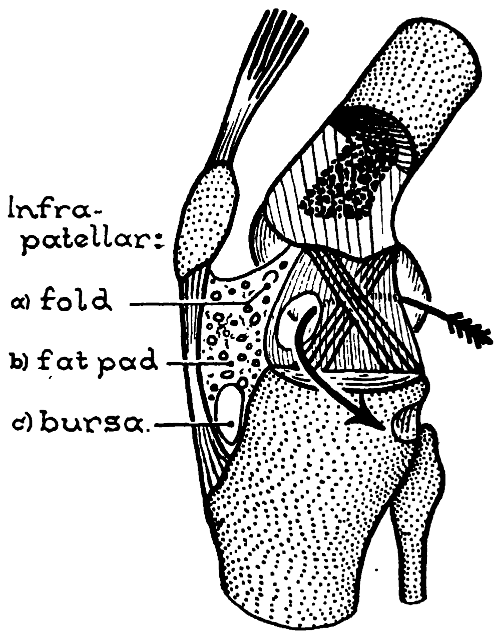


FIG. 483. The intercondylar septum (viewed from medial side).

size; generally it is large and extends backwards to the anterior cruciate ligament. It divides the septum into an anterior part, the ***infrapatellar fold,*** and a posterior part in which the anterior and posterior cruciate ligaments develop.

THE INFRAPATELLA SYNOVIAL FOLD (Lig. Mucosum) resembles the ligament of the head of the femur (lig. teres femoris) in being a tubular cone of synovial membrane which is flattened and triangular in shape. It has an anterior and a posterior surface. Its apex remains attached to the most anterior point of the

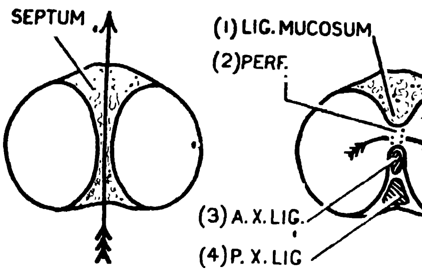


FIG. 484. Intercondylar septum as seen from above on the tibia. (A) early; (B) later Four derivatives are seen.

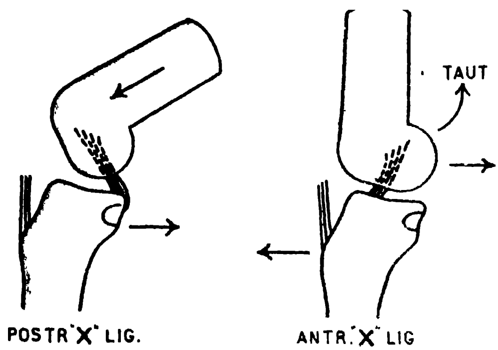


FIG. 485. The posterior cruciate ligament prevents forward displacement of the femur or backward displacement of the tibia. The anterior "X" ligament prevents backward displacement of the femur and hyperextension.

intercondylar notch of the femur; its open base extends from just below the articular cartilage of the patella to the anterior intercondylar area of the tibia; its sides are free and are prolonged into fringes, called the *alar folds*. The infrapatellar pad of fat (i.e., the fat behind the lig. patellae) is continued upwards into the infrapatellar fold and, in stout subjects, into the alar folds also. Injury to the knee may result in these folds being bruised.

THE CRUCIATE LIGAMENTS develop in the hinder part of the septum and cross each other like the limbs of a St. Andrew's cross; the one that is attached to the tibia below and in front is attached to the femur above and behind, and contrariwise. It is from their tibial attachments that they take their names. The anterior cruciate ligament, already observed to groove the antero-lateral part of the intercondylar notch, is attached above to the lateral femoral condyle; so, by exclusion the posterior cruciate ligament is attached above to the medial femoral condyle. Figure 485 makes clear that the posterior cruciate ligament prevents forward displacement of the femur on the tibia, and that the anterior cruciate ligament prevents backward displacement of the femur and hyper-extension of the joint. The posterior cruciate with the medial ligament may be regarded as "collateral" ligaments for the medial condylar joint, and the anterior cruciate with the lateral ligament as "collateral" ligaments for the lateral condylar joint.

A glance at the upper surface of the tibia suffices to answer the question, "How are side to side movements of the femur prevented?" It is seen that the articular surface of each tibial condyle rises gently towards the non-articular area and ends in a tubercle. The medial and lateral tubercles together constitute the *intercondylar eminence*. Side to side movement of the femur would cause one or other condyle to mount its respective incline. This the cruciate ligaments, obviously, would resist; so also would the medial and lateral ligaments during extension of the joint.

The Synovial Cavity and Communicat-

ing Bursae. The synovial cavity of the knee joint is not less complicated than the peritoneal cavity. Its intricacies fade into simplicity once you appreciate the following: (1) Developmentally, the joint possesses three synovial cavities: a patellar and two condylar. The partition separating the patellar from the condylar cavities disappears, leaving only the vestigial alar folds. The partition separating the condylar cavities from each other has been described above at some length as the intercondylar septum. Fluid can pass from one condylar cavity to the other either by way of the patellar cavity, that is, over the infra-patellar fold, or else through the hole that appears in the intercondylar septum between the infrapatellar fold and the anterior cruciate ligament; but, by no other way. (2) Each condylar cavity is divided into an upper and a lower part by the inwardly projecting semilunar cartilages. The two parts communicate around the free concave border of the semilunar. Loose coronary ligaments attach the convex margins of the semilunars to the upper end of the tibia below ($\frac{1}{4}$ inch) the articular margin (*fig. 486*). The lateral coronary ligament is worn away where the Popliteus tendon presses on it. (3) *Three bursae* communicate with the knee joint, *one joining each of the three primitive cavities* (*figs. 486, 487*). The bursae lie deep to the tendons of the Quadriceps Femoris, Popliteus, and medial head of the Gastrocnemius. The bursa deep to the Quadriceps Femoris tendon, known as the *suprapatellar bursa,* always opens freely into patellar cavity. The *popliteus bursa* opens into the lateral condylar cavity. It is situated between the popliteus tendon and all the hard structures (lateral semilunar, lateral tibial condyle, superior tibio-fibular joint) upon which the tendon plays; so, it is elongated. Sometimes the partition between this bursa and the superior tibio-fibular joint gives way and, so, brings the knee joint

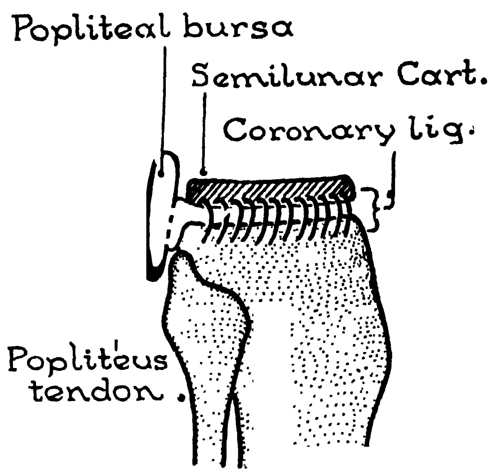


Fig. 486. Showing the popliteal bursa communicating with the joint cavity, and the coronary ligament attaching the convex border of the semilunar cartilage to the tibia.

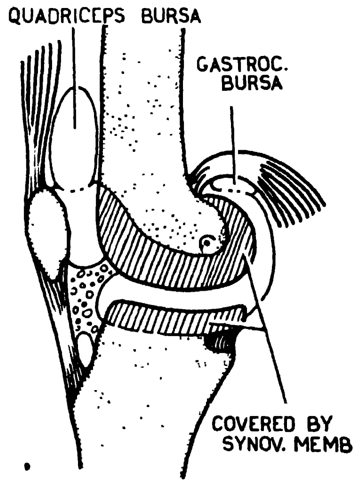


Fig. 487. Showing the Quadriceps Femoris and Gastrocnemius bursae communicating with the joint cavity.

and the superior tibio-fibular joint into communication. The bursa deep to the medial head of the Gastrocnemius very commonly (43% of 528 limbs, C. G.

Smith) communicates with the medial condylar cavity. This bursa communicates with a bursa deep to the Semimembranosus and, so, may bring the semimembranosus bursa and the knee joint into communication.

EXTENT OF THE SYNOVIAL CAPSULE. (*fig. 488*). An incision may be carried upwards on the tibia to within a quarter of an inch of its articular margin without opening the synovial cavity, except behind, where the popliteus bursa lies. How far may an incision be carried downwards on the femur? In front, to the top of the suprapatellar bursa, that is two finger's breadth above the patella; at the back, to the origins of the heads of the Gastrocnemius; at the sides the level must fall below the epicondyles, for they give attachment to the collateral ligaments, which are, of course, outside the synovial membrane.

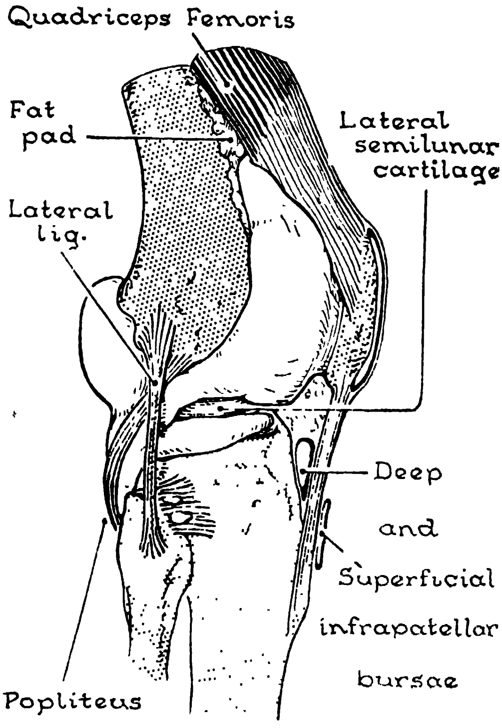


FIG. 488. Knee joint filled with latex to show the extent of the synovial capsule, lateral view.

The posterior cruciate ligament may be exposed from behind and the infrapatellar fold (lig. mucosum) from the front without opening into the synovial cavity, because they represent the posterior and anterior margins respectively of the intercondylar septum (*fig. 484*).

The Fibrous Capsule. Like other movable joints, the knee possesses a fibrous capsule as well as a synovial one. The ligamentum patellae and the medial ligament are part of the fibrous capsule. The fibrous capsule is completed in front and at the sides by expansions from the Vasti, Sartorius, Gracilis and Semitendinosus, Biceps and ilio-tibial tract. Behind, it is composed of fibers that run parallel with the Popliteus, i.e., obliquely downwards and medially from femur to tibia; and one band, known as the *oblique posterior ligament*, is attached to the Semimembranosus tendon. These limit extension of the joint and medial rotation of the femur on the tibia. The lateral ligament and the Popliteus tendon lie between the synovial and fibrous capsules. From their direction it would seem that both the medial and lateral ligaments restrict medial rotation of the femur on the tibia. The semilunars act as carriages for the femoral condyles; this is especially true of the lateral semilunar. They also serve as packing.

Relations. All the muscles crossing the joint are relations of the joint. The *ilio-tibial tract* is to be noted especially, on account of its great protective value to the exposed lateral side of the knee. It is placed between the ligamentum patellae and the tendon of the Biceps; it alone separates the skin from the synovial membrane. The lateral popliteal nerve (peroneal n.) follows the pos-

TABLE 18

Muscles Acting upon the Knee Joint (All the Muscles That Cross It)

NERVE SUPPLY	MUSCLES	ACCESSORY ACTIONS	MAIN ACTIONS
Sup. Gluteal Inf. Gluteal	Ilio-tibial tract T. Fasciae Latae Gluteus Max. (pt.)	Retain knee in the extended position	Extensors
Femoral	Quadriceps Femoris Rectus Femoris V. Intermedius V. Lateralis V. Medialis	Responsible for the final "screw home" movement	
	Sartorius	Rotate leg medially	Flexors
Obturator	Add. Gracilis		
Tibial division of sciatic	S. Tendinosus S. Membranosus Popliteus		
	Gastrocnemius Plantaris		
	Biceps (Long)	Rotate leg laterally	
Peroneal division of sciatic	Biceps (Short)		

terior border of the Biceps. The medial popliteal nerve (tibial n.) is behind the popliteal vein, which in turn is behind the popliteal artery. The popliteal artery is applied to the back of the fibrous capsule and is bound down by its five articular branches (*fig. 412*).

Blood and Nerve Supply. Of the five articular branches, the middle genicular a. passes forwards and supplies the structures in the intercondylar septum. The two medial and two lateral genicular aa. course deep to all muscles and ligaments they encounter, and embrace either the femur or the tibia. The lateral inferior genicular a. is an exception in as much as it passes (a) *behind the Popliteus tendon,* and then (b) runs along the margin of the lateral semilunar. These arteries anastomose with each other, with the descending branch of the lateral femoral circumflex, the descending genicular, and the anterior and posterior tibial recurrent arteries. The nerve supply is derived from the femoral n., via branches to the Vasti and the saphenous nerve; the obturator n. via the branch to the Adductor Magnus; and the tibial and peroneal *branches of the sciatic n. via the 5 genicular* branches of the medial and *lateral popliteal nn, which accompany the respective* arteries.

Bursae about the Knee, in summary. *Of these, there are eleven or more.* Thus:

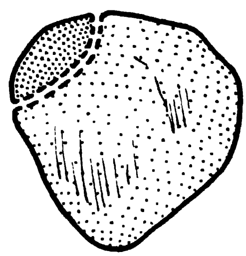


FIG. 489. Bipartite patella: a condition which is commonly bilateral.

3 communicate with the joint—Quadriceps (suprapatellar), Popliteus, and Medial Gastrocnemius.

3 beside the patella or lig. patellae—prepatellar, superficial infrapatellar, and deep infrapatellar.

2 Semimembranosus bursae—the one between the Semimembranosus and Gastrocnemius tendons usually communicates with the Gastrocnemius b. and so may communicate indirectly with the knee joint; the other lies between Semimembranosus tendon and the tibial condyle.

2 superficial to the collateral ligaments—the one between the lateral lig. and the overlying Biceps tendon; the other between the medial lig. and the three overlying tendons (Sartorius, Gracilis and Semitendinosus). The latter is commonly continuous with a bursa between Sartorius superficially and Gracilis and Semitendinosus deeply.

1 or more bursae between the superficial and deep parts of the medial ligament.

Epiphyses. The more actively growing ends of the femur and tibia are at the knee. *The lower epiphysis of the femur* begins to ossify about the ninth fetal month and fuses with the diaphysis about the 19th year. The epiphyseal line runs through the adductor tubercle, along the intercondylar line, and shaves the upper ends of the cartilage of the condyles. Four blunt prongs from the diaphysis fit into four shallow cups in the epiphysis (*fig. 381*).

The upper epiphysis of the tibia includes the groove for the Semimembranosus on the medial condyle, the facet for the fibula on the lateral condyle, and the tibial tubercle. Ossification begins before birth or soon after birth; fusion occurs about the 19th year.

The patella begins to ossify about the third year, generally from a single center. The supero-lateral angle may remain unossified (emarginate patella) or may ossify independently (*fig. 489*).

THE ANKLE JOINT

General Observations and Considerations. Before dissecting the joint or studying prepared dissections, we shall collect the scattered facts regarding it that are already ours.

1. In walking, the Triceps Surae (i.e., two heads of the Gastrocnemius and the Soleus) raises the heel from the ground, that is to say, it causes *plantar-flexion* of the ankle joint. During the act of advancing the limb, the four anterior crural muscles cause the foot to clear the ground, that is to say, they cause *dorsi-flexion*. The value of the ankle joint resides in this hinge action, in this to and fro movement in walking.

2. The weight of the body is transmitted to the talus through the tibia. The malleoli grasp the sides of the talus (*fig. 490*).

3. The sharp tip of the fibular malleolus is felt $\frac{3}{4}''$ below the level of the blunt end of the tibial malleolus. The top of the sustentaculum tali of the calcaneum is felt $\frac{3}{4}$ of an inch below the tibial malleolus and, therefore, on a level with the tip of the fibular malleolus. It follows, therefore, that the fibular malleolus extends the whole depth of the lateral side of the body of the talus and that $\frac{3}{4}$ of an inch of the medial side are not covered by the tibial malleolus. Hence, the lateral side of the body of the talus is $\frac{3}{3}$ articular, and the medial side is $\frac{1}{3}$ articular and, as we shall see, $\frac{2}{3}$ ligamentous (*figs. 491, 492*).

4. The sides of the malleoli and of the shafts of the bones above them are subcutaneous; that is to say, there are no muscles at the sides of the ankle. They

are grouped in front and behind as they obviously should be at an ideal hinge joint.

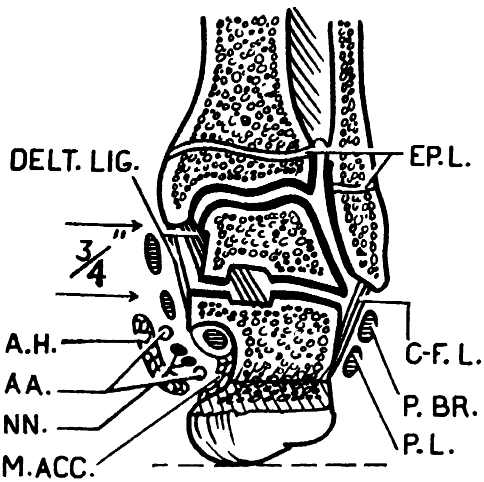


FIG. 490. A coronal section of the ankle joint and of the posterior and anterior talo-calcanean joints.

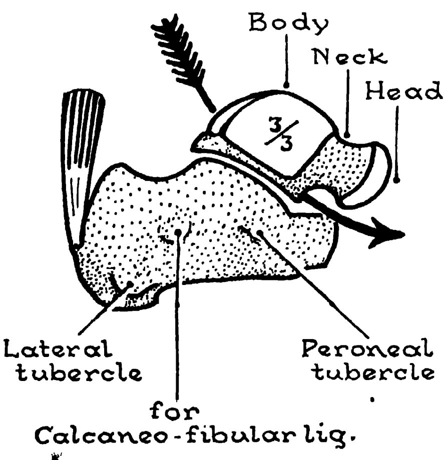


FIG. 491. Lateral aspect of calcaneum and talus. The lateral surface of the body of the talus is three-thirds articular. The arrow traverses the tarsal tunnel. (tarsal sinus).

5. Because of the hinge movements, the upper surface of the body of the talus is necessarily articular and convex from before backwards, and the under aspect of the lower end of the tibia is necessarily articular and concave.

6. In lower mammals, such as the sheep, the ankle joint is unquestionably a pure hinge joint in which movements are necessarily restricted to flexion and extension, because an antero-posterior

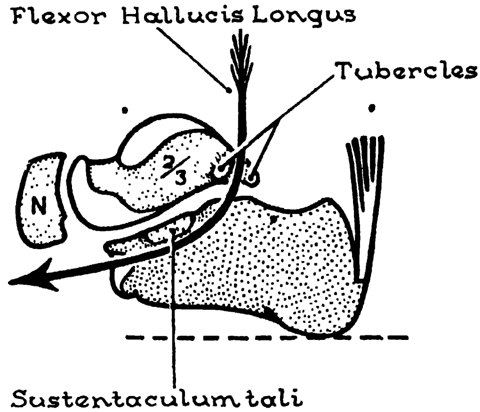


FIG. 492. Medial aspect of calcaneum and talus. The medial surface of the body of the talus is one-third articular; two-thirds rough for ligament.

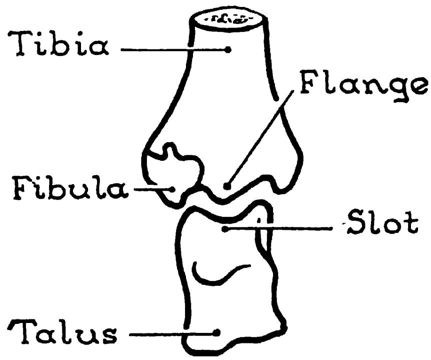


FIG. 493. The ankle joint of the sheep.

flange projects downwards from the middle of the lower end of the tibia and fits into a corresponding slot in the talus (*fig. 493*). The flange is the equivalent of an "intermediate malleolus". In man this feature, though not pronounced, is sufficiently well marked to produce a broad shallow groove on the upper surface of the body of the talus and to suggest

that the joint is fundamentally a pure hinge joint, as in the sheep.

7. With the exception of the tendo calcaneus, all muscles or rather all tendons crossing the ankle joint—4 in front, 5 behind—pass forwards to be in d into the foot anterior to the mid-tarsal joint (*fig. 494*). On contracting they tend to produce forward dislocation of the leg bones at the ankle joint. No muscles arise from the tibia or fibula and pass backwards to counteract this tendency..

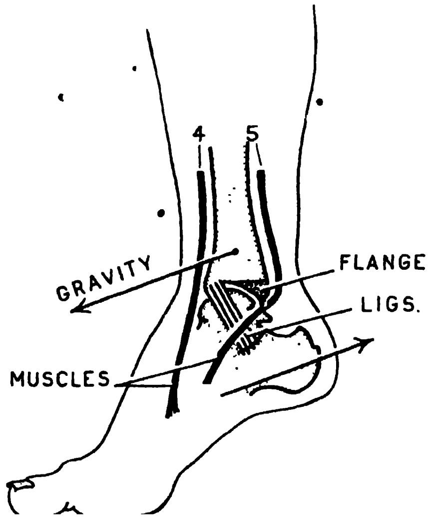


FIG. 494. At the ankle joint the ligaments and bones resist the forces of the muscles and of gravity.

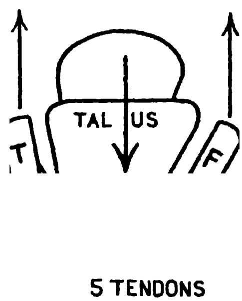


FIG. 495. Diagram of the ankle joint in horizontal section to show that the ligaments and the wedge-shape of the socket prevent backward displacement of the talus.

8. When we rise on our toes, the force of gravity also tends to displace the leg bones forwards.

9. The strength of a joint depends upon four factors: (a) Bones, (b) Ligaments, (c) Muscles, and (d) Gravity.

The muscles and gravity here tend towards forward displacement of the leg bones; so, it falls to the bony parts and the ligaments to resist this.

10. This demands that the socket shall be so fashioned that it cannot slide forwards on the talus,

11. and that the ligaments shall pass downwards and backwards.

Bony Parts. These include (a) parts of the talus and (b) its socket.

The Talus. It has been implied that the upper surface of the body of the talus is saddle-shaped and articular, and that it is continuous with an extensive facet for the fibular malleolus and with a restricted facet for the tibial malleolus. Note that the body is wedge-shaped (*fig. 495*), the broad end being in front, and that the fibular facet faces upwards as well as laterally.

The Socket comprises (a) the malleoli, whose posterior borders converge posteriorly, (b) the lower articular surface of the tibia, which is prolonged downwards posteriorly into a flange, and (c) the inferior transverse tibio-fibular ligament which deepens the socket posterolaterally and rubs against the talus. The wedge-shape, the flange, and the transverse ligament all assist in preventing forward displacement of the two leg bones.

Ligaments. The anterior and posterior parts of the capsule are loose to allow of hinge movements. *The Medial* or *Deltoid Ligament* (*fig. 496*) arises from the blunt end of the tibial malleolus and has 2 parts, a *superficial* and a *deep,* shaped like the corresponding parts of

the medial ligament of the knee: (a) The superficial or *"calcaneo-tibial" band* passes downwards and backwards to the upper part of the side of the sustentaculum tali. (b) The deep or *deltoid part* spreads out to be attached to the whole non-articular part of the medial aspect of the talus—from the medial tubercle behind to the neck in front. A few anterior fibers reach the navicular bone. Fibers placed between the sustentaculum and the navicular are continuous with the spring ligament and they may be said to suspend it (*fig. 496*).

The Lateral Ligament (*fig. 497*) has 3 parts: (a) The *calcaneo-fibular ligament* is a cord that passes downwards and backwards from in front of the tip of the fibular malleolus to a fulness on the side of the calcaneum. In shape and direction it resembles the lateral ligament of the knee. (b) The *posterior talo-fibular ligament* (*fig. 499*) passes medially and backwards from the fossa on the medial side of the fibular malleolus to the posterior tubercle of the talus (or os trigonum) and adjacent part of the talus. (c) The *anterior talo-fibular ligament* is a band that passes from the anterior border of the malleolus to the neck of the talus in front of the triangular fibular facet.

In Summary. Four ligaments pass backwards, thereby resisting forward displacement of the leg bones, or, which is equivalent, backward displacement of the foot. The "calcaneo-tibial" and calcaneo-fibular ligaments pass from the respective malleoli downwards and backwards to the calcaneum, and in so-doing span the talus. The posterior fibers of the deltoid ligament and the posterior talo-fibular ligament are very strong. They pass from the malleoli to the respective tubercles of the talus and to the adjacent parts of the talus (*fig. 499*).

The anterior talo-fibular ligament and the anterior part of the deltoid ligament pass downwards and forwards from the respective malleoli. The anterior talo-fibular ligament is the weakest ligament of the joint.

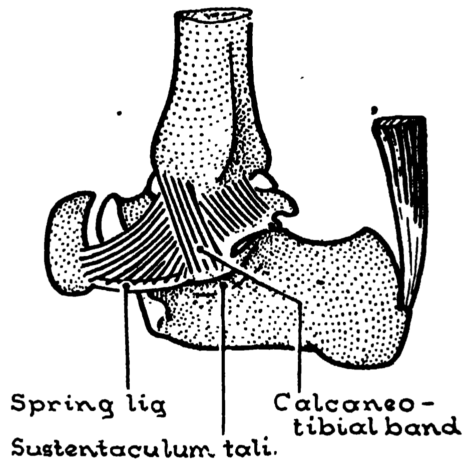


FIG. 496. The medial or deltoid ligament of the ankle joint.

FIG. 497. Lateral view of the ligaments about the ankle region. Observe that these ligaments are so directed as to prevent backward displacement of the foot bones.

The Synovial Membrane extends well forwards on to the neck of the talus. A puncture or a superficial incision made in front of the joint, when the toes are pointed, is liable to enter the joint cavity (*fig. 498*). Here, as at other joints, syn-

ovial folds extend between the articular surfaces, and a pad of fat is present.

Relations. In front, the anterior tibial vessels and nerve lie midway between the malleoli with 2 tendons on each side of them. Behind, the Fl. Hallucis Longus. tendon lies midway between the malleoli and there are 2 tendons behind each malleolus; the posterior tibial vessels and nerve lie between the Fl. Digitorum Longus and Fl. Hallucis Longus (*fig. 499*). The deltoid ligament is crossed by the Tibialis Posterior tendon; the cal-

upper surface of the joint; that of the tibia is a third of an inch above the joint (*fig. 490*).

Blood Supply. From the anastomoses around the joint.

Nerve Supply. From the anterior and posterior tibial nerves.

Further Observations. The most unstable position the joint can assume is plantar flexion, as when you rise on your toes, because the narrow end of the wedge-like body of the talus is then only loosely engaged by the malleoli, and

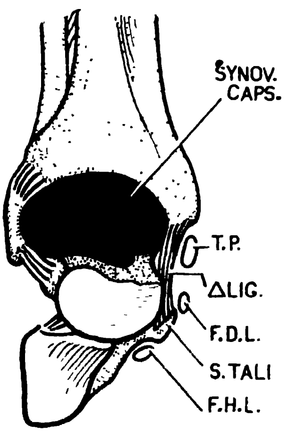


FIG. 498. The synovial cavity of the ankle joint, distended. The posterior surface of the mid-tarsal joint, i.e., anterior surfaces of the talus and calcaneum are shown. Note the positions of the long tendons in relation to the sustentaculum tali.

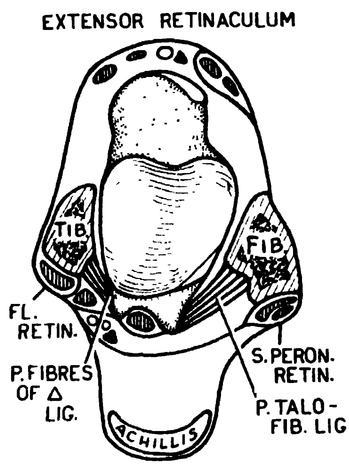


FIG. 499. Horizontal section through ankle joint showing (a) wedge-shaped socket, (b) direction of ligaments, (c) five posterior tendons, and (d) the investing and intermuscular deep fascia.

caneo-fibular ligament by the Peronei Longus and Brevis.

Movements. *Dorsi-flexion* (*Flexion*) —Tibialis Anterior, Peroneus Tertius, and the long extensors of the toes. *Plantar-flexion* (*Extension*)—Gastrocnemius and Soleus.

The 5 tendons passing behind the ankle are too close to the axis of the joint to act to advantage on the joint. In fact, if the tendo calcaneus is cut, the power to plantar-flex is lost.

Epiphyses. The lower epiphyseal plate of the fibula is at the level of the

slight degrees of inversion and eversion are permitted. The joint depends on the 2 tibial and 3 peroneal muscles, which act like the ropes of a rudder, to steady it. It is, perhaps, unfortunate that the Peroneus Tertius is not as strong as the Tibialis Anterior. It might then save the ankle from being sprained through forced inversion when you stumble with the toes inturned, as when stepping off the sidewalk. The anterior talo-fibular ligament, the weakest ligament of the joint, commonly suffers. To avoid this

risk, it is wise when walking over difficult ground to turn the toes out.

On going down hill you instinctively dig your heels into the ground, (a) because in this position of dorsi-flexion the broad edge of the wedge is closely grasped by the malleoli, and (b) because the heel is at the short end of a lever; the toes being at the long end.

The socket of the ankle joint is not rigid but supple (*fig. 500*). The suppleness is due (a) to the infero-lateral direction of the various tibio-fibular ligaments (*fig. 427*) and (b) to the obliquity of the fibular facet. The ligaments allow the fibula to move in 2 directions—cranially and laterally—hence, the socket yields by broadening. Because the fibular facet is not vertical but oblique, movement cranially results in further broadening.

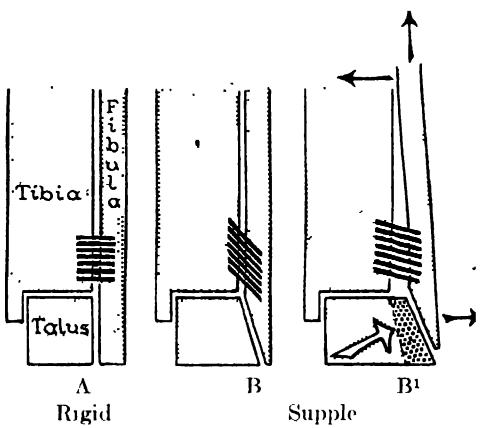


FIG. 500. Transverse tibio-fibular ligaments would make a rigid ankle socket; oblique ligaments make a supple socket.

If you grasp the shafts of an articulated tibia and fibia just above the ankle and squeeze them together, you will see the fibular malleolus spread laterally—provided the parts have not been allowed to dry.

THE JOINTS OF THE FOOT

The Talo-calcanean Joints. Between the hip bone and the heel there are four joints—hip, knee, ankle, and talo-calcanean. The last named, the talo-calcanean joint, is apt to be overlooked.

THE BONES CONCERNED. The entire body and part of the head of the talus rest upon the anterior two-thirds of the calcaneum and project slightly in front of it (*fig. 501*). The *Upper Surface of the Calcaneum* is divided into three areas: (a) The posterior third is saddle-shaped and above it lies a pad of fat. (b) The anterior third occupies a lower level than the posterior third and forms a horizontal platform (*fig. 502*). It presents medially a small facet (anterior calcanean facet) which is usually continuous posteromedially with a larger facet (middle calcanean facet) on the sustentaculum tali. (c) The intermediate third (posterior calcanean facet) occupies the inclined plane between the anterior and posterior thirds. In contrast with the combined anterior and middle calcanean facets which are concave, the posterior calcanean facet is convex. A deep groove separates the posterior facet from the middle facet; and, when the talus and calcaneum are in articulation, the groove

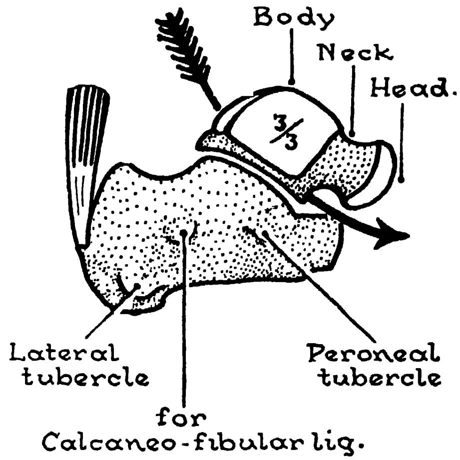


FIG. 501. The lateral aspect of the talus and os calcaneum. The arrow traverses the tarsal tunnel.

is converted into a tunnel, the *tarsal sinus*. A probe entering the sinus behind the sustentaculum tali will travel downwards, laterally, and forwards to debouch on to the lateral part of the anterior third of the upper surface of the calcaneum. This sinus lodges some fat through which run several fibrous bands, called the *interosseous talo-calcanean ligament*. These unite the respective bones.

The platform on to which the sinus debouches affords attachment to the stem of the inferior extensor retinaculum, the Extensor Digitorum Brevis, and the bifurcate ligament.

The talus and calcaneum have, then, three areas of contact: of these, the anterior is frequently continuous with the middle, and, were there no interosseous ligament, the middle would be continuous with the posterior.

THE LIGAMENTS. The 2 ligaments uniting the calcaneum to the talus are:

a. The interosseous talo-calcanean, which is not very strong (*figs. 490, 497*).

b. The lateral talo-calcanean, which is a mere slip (*fig. 497*).

The 2 ligaments uniting the calcaneum to the bones of the leg are:

c. The calcaneo-fibular portion of the lateral ligament of the ankle (*fig. 497*).

d. The "calcaneo-tibial" portion of the medial or deltoid ligament of the ankle (*fig. 496*).

All four ligaments take one and the same direction—downwards and backwards. They, therefore, prevent backwards displacement of the lateral longitudinal arch of the foot.

THE FIVE TENDONS. The five tendons (Peronei Longus et Brevis, Fl. Hallucis Longus, Tibialis Posterior, and Fl. Digitorum Longus) that play so important a part as stabilizers of the ankle joint play a similar rôle here at the talo-calcanean joints, the Fl. Hallucis Longus being especially important. It alone of the five has a direct influence on the joints. Leaving the tibia, it courses in the groove between the posterior and medial tubercles of the talus, and then passes alone beneath the sustentaculum tali (*fig. 492, 498, 499*).

MOVEMENTS. (1) Dorsiflex your foot so that the talus shall be firmly grasped by the malleoli and the ankle joint thereby locked. Then taking hold of your heel, observe that it can be rocked from side to side. Similarly, if you fill an ankle joint with plaster of Paris and thereby immoblise it, you can readily satisfy yourself that movements of inversion and eversion take place at the talo-calcanean joints. (2) Examination of the articulated foot shows that the talus can slide like a bolt on its long axis which runs downwards, forwards, and medially (or upwards, backwards, and laterally) causing the medial spring of the foot to glide on the lateral spring. This adds to the elasticity of the foot.

Observation. The apex of the fibular facet of the talus resembles the cutting edge of a chisel. Should one fall from a height on to ones heels this chisel-like edge may drive its way into the calcaneum (*fig. 491*).

The anterior talo-calcanean joint cavity is continuous with that of the talo-navicular joint, on which account the two joints are referred to collectively as the talo-calcaneo-navicular joint.

The Transverse Tarsal Joint (Midtarsal Joint) has two component parts:

(1) The Talo-navicular Joint,

(2) The Calcaneo-cuboid Joint.

They are joints of inversion and eversion and as such are complementary to the talo-calcanean joints (*figs. 498, 502*). Indeed, if you drive a nail upwards through the calcaneum and talus, thereby

immobilising the talo-calcanean joints, you will find that the movements of inversion and eversion are very greatly restricted.

Inversion and Eversion. To invert the feet is so to rotate them that the soles come to face each other. To evert is to rotate them in the opposite direction. If you examine the feet of a young fetus or even of a child at birth, you see that the feet are inverted. A fetus might clap its feet almost as easily as an adult can clap his hands. It is not until the child is a year or more old and learns to walk that it is able to evert its feet sufficiently to metatarsals, to adjust themselves to the irregularities of the ground. They are, therefore, of greater importance to a country dweller than to one living in a city. Even to a city dweller, however, they are necessary to the distribution of the weight of the body in proper ratio amongst the heads of metatarsals (p. 486).

When the ankle joint is plantar-flexed and the narrow end of the body of the talus loosely engaged by the malleoli, a slight amount of inversion and eversion can take place at the ankle joint, but this probably is not beneficial.

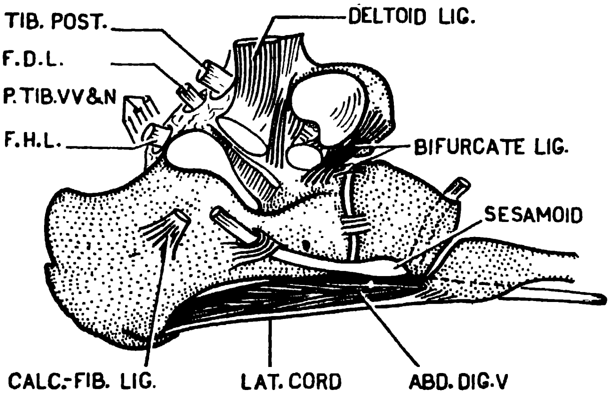


FIG. 502. The talus has been removed to show its bed.

place them flat (plantigrade) on the floor. This eversion is brought about partly by a change in direction of the neck of the talus and partly by a relative increase in the size of the bones on the medial border of the foot.

Inversion is not a matter of rotating on an axis passing through the heel and along the middle toe. It is, in fact, easily seen that the movement involves adduction of the front of the foot. Is any useful purpose served by the movements of inversion and eversion that take place at the talo-calcanean and transverse tarsal joints? They allow the bearing points of the foot, namely, the medial tubercle of the calcaneum and the heads of the five

OBSERVATIONS. a. On palpating the dorsum of the inverted foot, the front of the head of the talus and the anterior aspect of the calcaneum are found to be partly uncovered. Evidently inversion and eversion take place here.

b. Invert slightly against resistance and note by inspection and palpation that the Tibiales Anterior et Posterior are in action.

c. Evert and by palpation (not always easy) note that the three Peronei are in play. The five muscles of inversion and eversion must clearly find attachment to the foot in front of the transverse tarsal articulation.

d. The hollowed-out navicular bone

forms a socket for the head of the talus; so, the articulation is ball-and-socket in conformation but not in movements because encumbrances, in the form of adjacent bones and ligaments restrict its movements to gliding, i.e., the joint is of the plane or arthrodial variety.

e. Dorsal, interosseous, and plantar ligaments unite the cuboid to the navicular and cuneiforms; so, when the two tibial muscles cause inversion, the cuboid cannot choose but follow.

f. From this it may be concluded that of the opposed surfaces of the calcaneum and cuboid, one must be convex from side to side, the other concave (*fig. 438*).

THE **Talo-navicular Joint** is functionally part of the transverse tarsal joint. It also functions with the anterior talo-calcanean joint; it shares a common synovial cavity with it; and the two are referred to collectively as the *talo-calcaneo-navicular joint*. It is an essential part of the mechanism of inversion and eversion.

On the dorsum of the foot a weak band of fibers, the dorsal talo-navicular ligament, stretches from the neck of the talus to the navicular. Cut through it and thereby open into the talo-navicular joint Then, turning to the lateral aspect of the foot cut across the cord-like calcaneo-fibular, the slender lateral talo-calcanean, and the bandlike interosseous talo-calcanean ligaments. This leaves the talus attached to the leg bones, and the deltoid ligament remains intact. On bending medially the foot so-treated, the extensive socket for the whole articular part of the head of the talus is exposed.

The socket is formed in front by the posterior surface of the navicular (talo-navicular joint); posteriorly, by the middle and anterior calcanean facets (anterior talo-calcanean joint); and, between the under surface of the navicular and the sustentaculum tali by the *plantar calcaneo-navicular ligament*, commonly called "the spring ligament" (*fig. 503*). The spring ligament is continuous medially with the deltoid ligament, which suspends it from the tibial malleolus. It is sandwiched between the Tibialis Posterior, which supports it below, and the head of the talus which lies above it, and which in turn it supports. Where it is compressed between the tendon and the bone, it is fibro-cartilaginous; but its attachments remain pliable and ligamentous, like those of the semilunar fibro-cartilages of the knee. The deltoid ligament completes the capsule medially, the interosseous talo-calcanean ligament

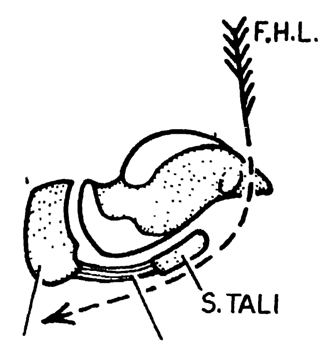


FIG. 503. The spring ligament. The arrow indicates the position of the Fl. Hallucis Longus tendon.

posteriorly, and the calcaneo-navicular part of the bifurcate ligament laterally.

The Bifurcate Ligament is attached posteriorly to the front of the upper surface of the calcaneum. The medial fibers (calcaneo-navicular band) of this V-shaped ligament pass forwards to the lateral surface of the navicular bone; the lateral fibers (medial calcaneo-cuboid band) pass to the medial surface of the cuboid bone. Thus the two bands form collateral ligaments for the respective joints.

The portion of the head of the talus that rests upon the "spring ligament"

is at the summit of the medial arch of the foot (*fig. 448*). If the Tibialis Posterior becomes weak or paralyzed, the "spring ligament", having an undue strain to bear, stretches, and the head of the talus, like the apex of a wedge, descends forcing the anterior portion of the foot downwards and also laterally, a condition known as flat foot.

THE **Calcaneo-cuboid Joint** is an accessory joint of inversion and eversion. Medially, it is bounded by the *calcaneo-cuboid band* of the bifurcate ligament; dorso-laterally, by an indifferently weak band, the *lateral calcaneo-cuboid ligament.* Cut through these in order to see that the anterior surface of the calcaneum is rounded off medially (i.e., convex); that the posterior surface of the cuboid is concave from side to side, thus allowing of inversion; and that a process (the calcanean angle) projects from the lower and medial part of the cuboid backwards below the calcaneum. The upward thrust given by the Peroneus Longus to the cuboid is transmitted by this angle to the calcaneum. The joint is closed below by two ligaments, the long and short plantar ligaments.

The Long Plantar Ligament (*fig. 504*) is attached posteriorly to the plantar surface of the calcaneum in front of its medial and lateral tubercles. Anteriorly, its deep fibers gain attachment to the ridge on the cuboid, but its more superficial fibers pass beyond this and gain attachment to the bases of (2), 3, 4, (5) metatarsals (*fig. 504*). Incidentally, it converts the groove for the Peroneus Longus into a tunnel. The long plantar ligament is obviously a tie that stretches across the calcaneo-cuboid and cubo-metatarsal joints of the lateral arch of the foot.

The Short Plantar Ligament (plantar calcaneo-cuboid lig.) is fan-shaped, and is not completely exposed till the band-like long plantar ligament is reflected. It stretches from the anterior tubercle of the calcaneum (and the area in front of it) to the large area behind the ridge on the cuboid. It belongs solely to the calcaneo-cuboid joint and has, therefore, a shorter span than the long plantar ligament.

Note. Although the plantar ligament of the transverse tarsal joint has been described as having two parts, viz., plantar calcaneo-cuboid and plantar calcaneo-navicular, they function as one,

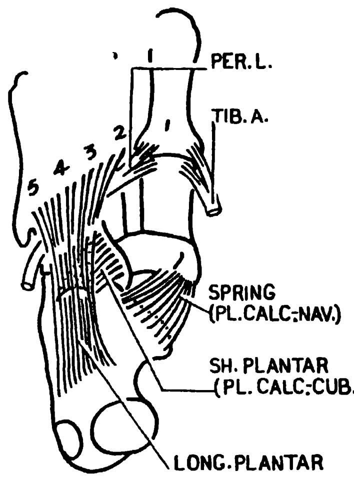


FIG. 504. Three plantar ligaments, and the two tendons that form a stirrup.

and they form an almost continuous thick sheet of parallel fibers that run forwards and medially from the calcaneum to the cuboid and navicular respectively.

The Joints of the Foot Distal to the Midtarsal Joint. These include five series of joints: the small intertarsal, tarso-metatarsal, inter-metatarsal, metatarso-phalangeal, and inter-phalangeal joints.

The *Metatarso-phalangeal and Interphalangeal Joints* are fashioned and supplied with ligaments like the correspond-

ing joints of the hand, the metatarso-phalangeal joint of the great toe with its two sesamoids being the most important of them. The ligaments of the metatarsal heads (deep transverse ligaments) extends to the hallux; in the hand the corresponding ligaments leave the pollex free.

The *Small Intertarsal Joints* (i.e., between cuboid, navicular, and cuneiforms), the *Tarso-metatarsal Joints*, and the joints between the *Bases of the Metatarsals* may profitably be considered together under the headings: (a) the side-to-side joints, and, (b) the end-to-end joints.

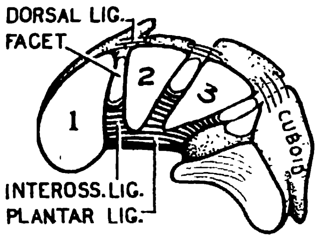


FIG. 505. The ligaments or ties of the "side to side" joints. Note that the cuboid supports the cuneiforms and the navicular.

THE SIDE-TO-SIDE JOINTS or those concerned in the transverse spring or arch of the foot have strong *plantar ligaments* which act as transverse ties (*fig. 505*). These ties are not limited to the plantar aspect but, as *interosseous ligaments*, extend dorsalwards between the individual bones, being absent only between the bases of metatarsals I and II. The *articular facets* are generally situated near the dorsal part of the surface, where ligaments would have least value. The *dorsal ligaments* are weak. This construction is obviously mechanically ideal. The facets are flat and, so, allow of slight gliding movements. The navicular and cuneiforms are partly supported by the cuboid. The arch depends largely on the crossed insertions of the Tibialis Posterior and Peroneous Longus for its maintenance (*fig. 457*) and on the Adductor Hallucis Obliquus.

THE END-TO-END JOINTS or those concerned in the longitudinal springs or arches of the foot. Observe that the opposed anterior and posterior surfaces of all the bones of the foot are completely covered with cartilage, and that the joints, accordingly, do not possess interosseous ligaments (*fig. 445*). They have, however, ***strong plantar ligaments, weak dorsal ligaments***, and in some instances, ***collateral ligaments*** (*fig. 506*). The side-to-side facets are commonly continuous with the end-to-end facets.

The Lateral Longitudinal Arch or spring is formed by the calcaneum,

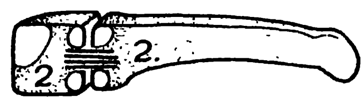


FIG. 506. The collateral ligament of an "end to end" joint.

cuboid, metatarsals IV and V (and their phalanges). It is a small arc of a large circle; that is to say, the arch is low (*fig. 448*). In the act of walking it commonly bears the weight of the body before the medial arch comes into play. It can yield or flatten at the hinge surfaces between the cuboid and metatarsals IV and V. The Peroneus Longus passes under the cuboid at the summit of the arch, which is near its midpoint, and acts as a sling for it, and the upward thrust it gives to the cuboid is transmitted to the calcaneum by the calcanean angle of the cuboid.

The ties of the arch are especially: the short and long plantar ligaments, the plantar aponeurosis, the lateral cord of the plantar fascia, the Abductor Digiti V, and the F. Digitorum Longus.

The Medial Longitudinal Arch or spring is formed by the calcaneum; talus, navicular, 3 cuneiforms, 3 medial metatarsals (and their phalanges), and the sesamoid bones. It is a large arc of a small circle; that is to say, the arch is high. At its summit, placed at the junction of its posterior one-third with its anterior two-thirds, lies the head of the talus with the sustentaculum tali behind it and the navicular in front. The Tibialis Posterior is largely (⅔) inserted into the tuberosity of the navicular bone, but the part (⅓) that passes below the spring ligament acts as a sling for the arch. At the hinge surfaces between the talus and the navicular and also between the navicular and the three cuneiforms, the spring or arch can flatten and recoil.[1]

The ties of the arch are especially: the spring (plantar calcaneonavicular) ligament, the plantar aponeurosis, the short muscles of the big toe, the Tibialis Posterior, and the Flexor Hallicus Longus.

The plantar aponeurosis, the Flexor Digitorum Brevis, and the Flexor Digitorum Longus are common to both arches.

The insertions of the Tibialis Posterior and Peroneus Longus require special note. The fasciculi of the Tibialis Posterior spread out like the fingers of an outstretched hand to grasp practically every tarsal and metatarsal bone in front of the mid-tarsal joint, and some of them become detached or segmented to form plantar ligaments. The Peroneus Longus crosses the fasciculi of the Tibialis Posterior X-wise to be inserted into the adjacent parts of the first cuneiform and first metatarsal. The combined effort of these two muscles largely creates the transverse arch and helps to support the longitudinal arches.

[1] Examination of the dried bones does not reveal this; they must be examined fresh, with the cartilage on.

The Ligaments of the Fore-part of the Foot. These are not scattered haphazard, as might at first sight appear, but are so disposed as to resist certain tractions and pulsions. Accordingly (1) the dorsal, interosseous, and plantar ligaments between any two bones, having a common purpose, have a common direction; further, from figure 507 it may be noted that (2) the ligamentous

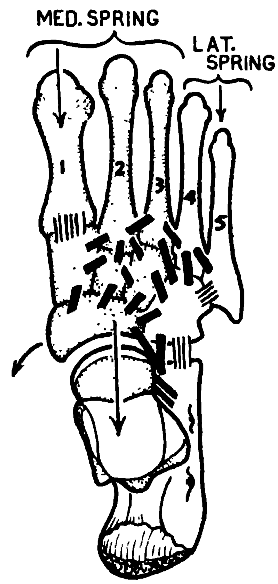


FIG. 507. The dorsal ligaments of the foot are not scattered haphazard (see text).

bands uniting the individual bones of the lateral spring to each other and to the bones of the medial spring, all—or practically all—take a common direction; this is the *direction of resistance* (a) to the backward pull of the muscles inserted into the lateral spring, and (b) to backward thrusts applied to 4th and 5th toes (as in walking and kicking); and similarly that (3) the ligamentous bands of the medial spring are so directed that the backward thrust given to the 1st metatarsal (as in rising on the ball of the

big toe in walking, and in kicking) is dispersed laterally to the 2nd and 3rd metatarsals which, therefore, share in conducting the thrust via the cuneiforms and navicular to the talus and so to the tibia.

Mobility of the Metatarsals. Dorsi-plantar Mobility. With one hand steady your foot while with the other you grasp successively the heads of your metatarsals (as you did previously with the heads of your metacarpals, p. 137), noting that the 5th can be plantarflexed and dorsiflexed freely, the 4th less freely, the 3rd, 2nd, and 1st very slightly, if at all. By actively plantarflexing your toes (comparable to clenching the fist (*fig. 219*), the same facts are demonstrated, namely, (a) that the two cubo-metatarsal joints are hinge joints and (b) that the three cuneo-metatarsal joints are not. In fact, any plantarflexion or dorsiflexion involving the 3rd, 2nd, and 1st metatarsals takes place almost entirely at the cuneo-navicular joints and, if more than slight, it implies lax ligaments.

Side-to-Side Mobility. With one hand gently press the shafts of your metatarsals together. Place the thumb of the other hand on the dorsum of your foot between the contiguous heads of two metatarsals and place the fingers opposite it on the sole; then, by bringing the thumb and fingers together, force the heads apart, note the extent of separation permitted. In most feet the 1st metatarsal moves appreciably, the 2nd and 3rd not at all, the 4th slightly, and the 5th considerably; an examination of the cartilage-covered bases of the metatarsals supplies the reason (*fig. 445*).

Standing. Weight Distribution. On previous pages the foot has been likened to a tripod, to an arch, and to a spring; and each of the three similies is a useful conception. It has been shown by means of a specially designed instrument that the body-weight of a person weighing say 120 pounds and "standing relaxed in a naturally held position" is distributed through the feet as follows: 60 pounds is distributed through each foot; of this, 30 pounds is through the hind-part (calcaneum) and 30 pounds through the fore-part, as might be expected since the line of gravity passes slightly in front of the ankle joint. Now, the fore-part of the foot has six points of contact with the ground, namely, the two sesamoids under the head of the first metatarsal and the heads of the lateral four metatarsals, each supporting approximately 5 pounds; the first metatarsal through its sesamoids supports a double load. (D. J. Morton.)

Since the heads of all the metatarsals make contact with the ground, it is evident that they do not form an arch (the so-called "anterior transverse arch" of the foot has no existence), but the bases of the metatarsals take part in the (posterior) transverse arch. Inspection and manipulation reveal that an almost identical condition obtains in the hand.

If the posture of the body is not erect, but forwardly inclined or stooping, the fore-part of the foot supports an undue proportion of the body-weight; and, if backwardly inclined, more weight is supported by the heels. In walking, the ball of each foot alternately supports the total body-weight which, of course, is four times the weight it supports in standing.

If, in walking, the feet are turned out at more than 30° to 40° from each other, the head of the talus tends to bear down on the spring ligament, forcing the fore-part of the foot into abduction.

If the ligaments at the base of a metatarsal are lax, that metatarsal, being mobile, will largely cease to be a weight-distributing bone.

Arch Support. It has long been the teaching that muscles are all important for the support of the arches of the foot and that ligaments here, as elsewhere, if submitted to strain will stretch and so lose their virtue. It would appear that this view must be revised. R. L. Jones working with foot-and-leg specimens disarticulated at the knee and with apparatus designed to apply varying loads vertically on the tibia of this experimental leg, to apply tensions to the long tendons of the foot, and to register results, has calculated:

(1) that the three deep posterior tibial muscles (Tibialis Posterior, Fl. Digitorum Longus, and Fl. Hallucis Longus) and the Peroneus Longus are relatively unimportant as plantar flexors of the ankle joint and could not account for more than 5% of the pressure produced at the ball of the foot on plantar flexion.

(2) that of the total tension stress of the longitudinal arch of the foot, not more than 15% to 20% is borne by the three deep posterior tibial muscles and the Peroneus Longus.

(3) that the greater part of the stress is borne by the plantar ligaments and plantar aponeurosis, and that the short plantar muscles also contribute.

(4) that the chief function of the invertor and evertor muscles is to preserve a relative constancy in the ratio of the weight distribution amongst the heads of the metatarsals.

(5) that the Peroneus Longus is more than four times as efficient in producing a shift of pressure from the lateral metatarsal heads to the first metatarsal head as the Tibialis Posterior or Fl. Digitorum Longus are in producing a shift from the first metatarsal head to the lateral heads.

(6) that lateral inclination of the tibia (as in knock-knee) shifts the weight towards the first metatarsal, and that medial inclination (as in bow-legs) shifts it towards the lateral metatarsals.

(7) that in walking, the Tibialis Anterior is relaxed and does not support the arch while the weight of the body is on the ball of the foot. In fact, it plays no part in arch support.

(8) that in walking, the Tibialis Posterior and Peroneus Longus are relaxed so long as the heel and the ball of the foot are on the ground; and that they contract (but not maximally) as soon as the ball of the foot assumes the total weight of the body. This they do slightly in order to support the arch but mainly to serve the functions of invertors and evertors.

(9) that failure of the arch is related to the duration of the stress to which it is subjected rather than to the severity of the stress; e.g., athletes and those who walk much subject their arches to great stresses intermittently; whereas those who stand immobile subject their arches to relatively continuous stress, and it is these latter who develop arch trouble.

Walking. In the act of walking, first the heel is placed on the ground, then the ball of the little toe, followed by the balls of the 4th, 3rd, 2nd and finally of the big toe. As one next steps off with the other foot, first the heel leaves the ground, and, as it rises, the hinge movement of dorsiflexion takes place at the metatarsophalangeal joints (*fig. 494*), the toes in the meantime remaining firmly applied to the ground. Finally, as the ball of the big toe leaves the ground, the heel of the opposite foot is making contact with the ground.

Function of the Toes. In man the toes are not used for prehensile purposes; their function is to press into the ground and there to form a friction surface during the act of walking. They afford a purchase for the forward thrust of the body at each step. If there were no toes, when

the heel left the ground one would rise on the uneven and unsteadied heads of the metatarsals.

Muscles. The Gastrocnemius and Soleus raise the heel from the ground. The Flexores Hallucis Longus et Brevis support the weight of the body at the big toe. The two Tibiales and the three

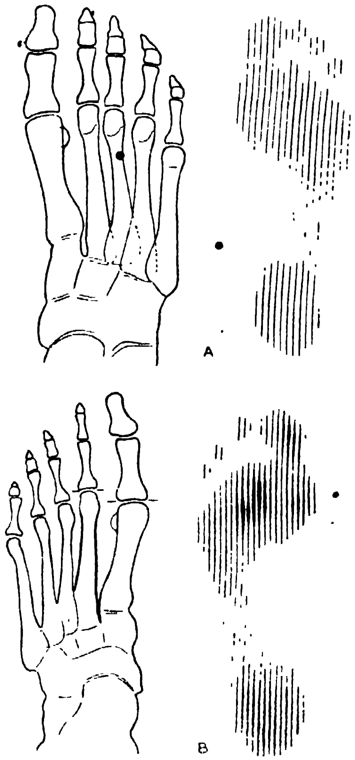


FIG. 508. (A) Tracing of a radiogram and an accompanying print of a normal right foot made by walking on a corrugated mat. (B) Tracing, and a print of a left foot with a short first metatarsal bone. (After Morton.)

Peronei steady the joints of the foot and ankle and prevent inversion and eversion, much as ropes steady the rudder of a boat.

When the foot is off the ground, the abductors of the hip (Glutei Medius et Minimus, and Tensor Fasciae Latae) prevent adduction of the body, i.e., prevent it from lurching to the opposite or unsupported side, and the medial rotators of the hip (the same three muscles) rotate the opposite side of the pelvis forwards, thereby lengthening the stride.

Weight Distribution. In walking, the head of each metatarsal has a weight-bearing contact with the ground; as shown by figure 508A which is the print of a normal foot made by walking on "a rubber mat with compressible corrugations. The mat was covered with an inked fabric, a layer of paper, and finally a strip of cloth to hold the others in position". The distribution of the pressure in the feet is registered by the width of the corrugations printed on the paper. Contrast this with figure 508 B, which is the print of a foot whose 1st metatarsal was short—a common atavism—with the result that the 2nd metatarsal had to carry more than its normal share of the load. This accounts for the increased thickness and dense shadow of the 2nd metatarsal in the radiogram, and for the width of the corrugations under the head of the 2nd metatarsal in the print. (D. J. Morton.)

Progression. In walking, the toes should be pointed nearly directly forwards in the line of progression, their position being controlled by the rotators of the hip joint. If turned considerably outwards, so that the medial side of the foot is directed forwards, in the line of progression, then the foot will tend to become everted at the talo-calcanean joints, the talus to be pressed against the fibular malleolus, the fore-part of the foot to be abducted (everted) at the mid-tarsal joint, and the head of the talus to descend.

THE BONES OF THE HAND AND FOOT COMPARED

The Pentadactyl Hand and Foot. The limbs of amphibia are evolved from fins

to be used as paddles in the water and as legs on the land. And, having the same function, all four limbs are built to the same design. Hence, we may speak of homologous parts of the upper and lower, or fore and hind, limbs.

The bones of the hand and foot of man, when compared with those of the water-turtle, are seen to retain the primitive generalized plan. The turtle has three proximal carpal and tarsal bones, the middle being the *os intermedium,* five distal carpal and tarsal bones, and several central bones, *ossa centralia,* on which the distal carpals and tarsals pivot (*fig. 509*). In man the preaxial bones (radius and tibia) become weight-bearing bones; the post-axial bones (ulna and fibula) cease to articulate with the triquetrum or calcaneum. The os intermedium becomes the lunate or posterior tubercle of the talus; the 4th and 5th distal bones fuse to form the hamatum or cuboid. One os centrale persists as an entity in most primates; in man it fuses with the dorsum of the scaphoid of the hand and becomes the navicular of the foot. The pisiform bone in man is perhaps derived from one of the ossa centralia, or it may be a sesamoid developed in the tendon of the Flexor Carpi Ulnaris and homologous with the epiphysis of the calcaneum, or possibly it is a vestigial extra digit.

The foot of man was no doubt at one time a prehensile organ like his hand and like the foot of primates in general, who have a short opposable big toe and no arch. The base of the 1st metatarsal retains evidence of its former freedom: (a) in not articulating with the second metatarsal base, (b) in not being bound to it with ligaments, and (c) in having the form of a lateral hinge joint. The remaining tarso-metatarsal surfaces closely resemble the corresponding carpo-metacarpal surfaces, thus: (*a*) the lateral four bones (metatarsals and metacarpals) articulate with each other by an almost identical arrangement of facets and are united by dorsal, plantar, and interosseous ligaments; (*b*) the 2nd and 3rd metatarsals and metacarpals are immobile, the 2nd because it is morticed between the three small bones (tarsals or carpals) with which it articulates, the 3rd because of its expansive plane base; (*c*) the 4th and 5th metatarsals and metacarpals are mobile, the joints at their bases being hinge joints.' The base of the 4th is quadrangular and articulates with two tarsals or carpals, the base of the 5th is roughly triangular and has a tubercle or tuberosity on its nonarticular side. The base of the 1st metatarsal is kidney-shaped.

With the loss of prehensile power the phalanges of the foot dwindle, those of the middle and ungual rows becoming nodular, and in the case of the little toe commonly fusing. In adaptation to walking, the tarsal bones enlarge; this is especially true of the hinder two. The metatarsal bones are compressed from side to side and elongated. The 2nd metatarsal outstrips the middle metatarsal in length and projects beyond it. The 2nd toe is, therefore, the longest toe though the 1st or hallux may equal or exceed it owing to the length of its phalanges. All three bones of the hallux are exceptionally stout. In man a medial arch develops and the elongated hallux comes into line with the medial border of the foot; and when the child walks the neck of the talus straightens and the navicular, 1st cuneiform, and medial border of the foot lengthen.

Ossification. X-ray photographs show that no carpal bone has begun to ossify at the time of birth; save occasionally the capitate and hamate in the

female; but the calcaneum, talus, and cuboid of the tarsus are well ossified. The order of ossification is different in the metacarpus and tarsus. In the carpus the sequence is spiral from capitate to hamate, triquetrum, lunate, scaphoid, trapezium (greater multangular), and trapezoid (lesser multangular), and pisiform (*fig. 128*). In the tarsus it is irregular from calcaneum to talus, cuboid, 3rd, 1st, 2nd cuneiform, navicular, epiphysis of calcaneum. The calcaneum is the only tarsal or carpal bone that regularly has an epiphysis. The epiphysis includes its entire posterior surface and its medial and lateral tubercles. It appears about the 11th year and fuses about the 17th year. Whatever the origin of the pisiform bone may be, it behaves as a sesamoid bone developed in the tendon of the Flexor Carpi Ulnaris, the distal part of the tendon being the piso-metacarpal ligament, and it begins to ossify about the 12th year. Perhaps it is homologous with the epiphysis of the calcaneum, which (like the sesamoids below the head of the 1st metatarsal also) begins to ossify about the 11th year. It may be regarded as a sesamoid developed in the tendo Achillis which fuses with the calcaneum, the distal part of this tendon being the long plantar ligament.

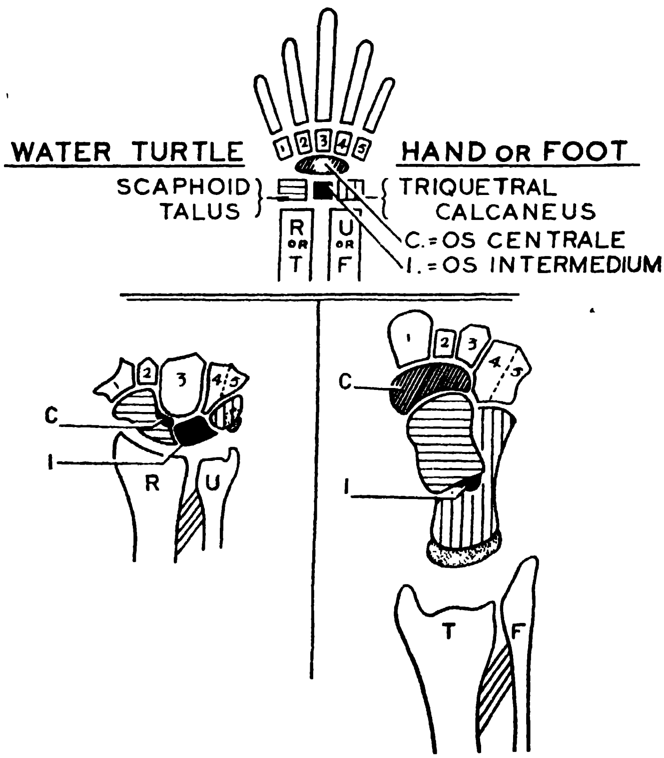


FIG. 509. Homologies in the bones of the hand and foot.

The metacarpals, metatarsals, and phalanges are long bones, and each has a primary center for the body, which appears about the 3rd fetal month (later in the case of the phalanges of the foot)

and a secondary pressure epiphysis for the bases of the 1st metacarpal, 1st metatarsal, and all the phalanges, and for the heads of the 2nd-5th metacarpals and metatarsals. These appear about the 3rd year and fuse about the 18th year (*fig. 127*).

The metacarpal of the thumb and the metatarsal of the great toe ossify, therefore, like phalanges. This gives rise to the view that phylogenetically, they are phalanges; that the trapezium and medial cuneiform are vestigial metacarpals and metatarsals respectively, and that the first distal carpal and tarsal are represented by the ossicles occasionally found at the base of the 1st metacarpal and metatarsal. On the other hand, it may be that the middle phalanx, which is the last of the three phalanges to ossify, has dropped out from the pollex and hallux. It is not rare for epiphyses to occur at the head of the 1st metacarpal and at the base of the 2nd metacarpal.

Supernumerary Ossicles. A dozen or so have been described in both foot and hand. They are liable to be mistaken for fractures.

In the Foot the commonest ossicles are: (1) The *os trigonum* or separate posterior tubercle of the talus (*fig. 510*). Morphologically it is an ununited os intermedium. (2) The *tibiale externum* or separate navicular tuberosity. (3) A *bipartite medial cuneiform*, in upper and lower halves. (4) Of historical interest, though rare, is the os Vesalianum or ununited tuberosity of metatarsal V, described by Vesalius. (5) A fibro-cartilaginous nodule in the Peroneus Longus tendon latera to the cuboid is common and frequently it is ossified.

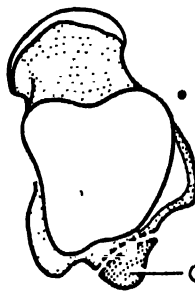


FIG. 510. Os trigonum: a condition which is commonly bilateral.

In the Hand: (1) An *os centrale* which remains discrete instead of joining the scaphoid. (2) A *bipartite scaphoid.* (3) A *radiale externum* or separate *scaphoid* tubercle. (4) A separate styloid process for metacarpal III.

SECTION VI

THE THORAX

CHAPTER 17

The thorax is the region between the diaphragm and the neck. It contains the heart and lungs; it is traversed by structures that pass from the neck to the abdomen; by expanding and contracting like bellows, it aerates the blood circulating in the lungs.

THE BONY THORAX

The thoracic cavity is the largest of the three great bony cavities—cranial, thoracic, and pelvic. Each of these, in addition to offering protection to the important viscus or viscera it contains, has diverse functions to perform, so each differs markedly from the other two in shape and construction. The bony thorax comprises: 12 vertebrae, 12 pairs of costae (ribs and costal cartilages) and 1 sternum.

The Upper Aperture of the Thorax is formed by the body of the 1st thoracic vertebra, the 1st ribs, 1st costal cartilages, and the intensely thick upper border of the manubrium sterni. It is like a kidney in shape, the body of the 1st thoracic vertebra representing the hilum; and like a kidney in size, its diameters varying from two by four inches to two and a half by five inches (*fig. 516*).

The Lower Aperture of the Thorax is formed by the lower six costal cartilages and the 12th rib on each side, the xiphoid process in front, and the body of the 12th thoracic vertebra behind. It is cut away like a morning coat. The 10th rib is the lowest rib seen from the front. The 11th rib is much longer than the 12th rib and reaches to within two or three fingers breadth of the iliac crest.

The Cavity of the Thorax also is kidney-shaped on transverse section (*fig. 511*). This is due to the fact that the ribs are carried backwards beyond the vertebral bodies almost as far as the tips of the spinous processes, where they bend to form angles. The transverse processes, which in this region act as buttresses for the ribs, are tilted backwards to allow of this. In consequence, the antero-posterior diameter of the thorax is least in the median sagittal plane and greatest in a lateral sagittal plane passing through the angles of the ribs. When one considers that the dome of the diaphragm rises to the level of the fifth or sixth rib, it becomes apparent that the bony thorax affords protection not only to the heart and lungs, but also to the upper abdominal viscera—notably the liver, stomach, and spleen.

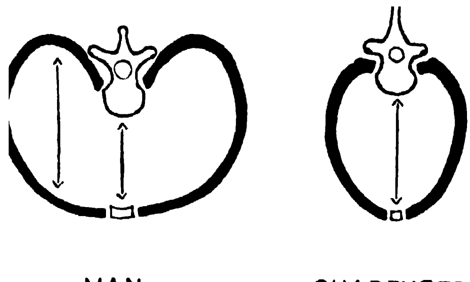


FIG. 511. Transverse section of thorax.

In the Quadruped the thorax is suspended between the forelimbs by the Serrati Anteriores and Pectorales; so, it is compressed from side to side. It is

heart-shaped on transverse section, the greatest sagittal diameter being in the median plane (*fig. 511*). The ribs have no angles. *In the child at birth* the chest is nearly circular. In the adult female it is slightly rounder than in the adult male.

The antero-posterior flattening of the thorax, the backward curvature of the ribs, the dorsal position of the scapula, and the broadening of the sternum are associated with man's upright posture (*fig. 27*).

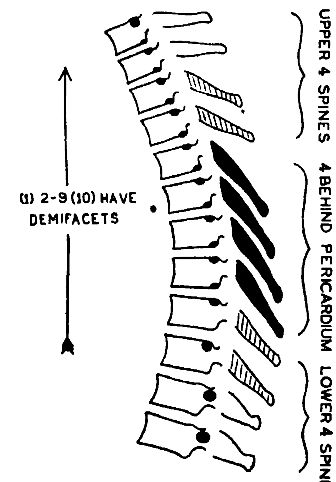


FIG. 512. Thoracic vertebrae, on side view, showing migration cranialwards of rib facets, and the inclinations of the spinous processes.

The Thoracic Vertebrae. The thoracic vertebrae have certain peculiarities and distinguishing features (*fig. 512*), the chief of which are these:

The Body of every thoracic or rib bearing vertebra had primitively, far back on its sides, a pair of facets for the heads of its own pair of ribs (i.e., the ribs that correspond numerically with it). In the case of vertebrae (1, 10), 11 and 12, these costal facets are large excavations. Owing to the fact that during development the remaining rib heads (2–9) have migrated cranialwards and have come to encroach on the bodies of the vertebrae numerically next above them, vertebrae 2–8 possess a superior and an inferior demifacet on each side. The first vertebra has generally a full superior facet and an inferior demifacet on each side; vertebra 9 has superior demifacets and usually inferior demifacets also, because rib 10 usually encroaches on it. The superior demifacets being, as it were, the primitive facets, are generally larger than the inferior ones. The costal facets of vertebrae (10), 11 and 12 are largely on the pedicles.

The bodies in the middle of the thoracic series are heart-shaped and are longer from

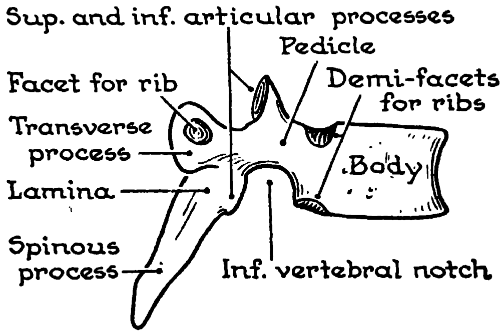


FIG. 513. A typical thoracic vertebra, side view.

before backwards than from side to side. Each body is deeper behind than in front and so contributes to making the thoracic portion of the vertebral column concave forwards (*fig. 513*). The upper and lower surfaces are flat, and the surface areas increase progressively from the first to the last, as might be expected. Vertebra 3 is narrow from side to side. The left sides of the bodies of vertebrae 5, 6, and 7 are commonly flattened by the aorta.

The Transverse Processes act as buttresses or fulcra for the ribs, and accordingly are strong and stout. They are directed, not laterally, but postero-later-

ally in conformity with the backward sweep of the ribs in man, who walks erect. On their tips are facets for the tubercles of the tibs. For reasons given on page 498, these are concave and in front of the tips of the 1st–7th transverse processes; flat and above the tips of the 8th, 9th, and 10th transverse processes; and absent from the 11th and 12th. The transverse processes become progressively shorter from the 1st to the 12th. The 11th and 12th are reduced and rudimentary, and do not act as fulcra for the floating ribs. The 12th is subdivided into three tubercles corresponding to the mamillary, accessory, and "transverse" processes of a lumbar vertebra.

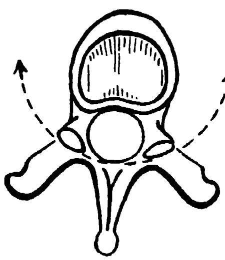


FIG. 514. The thoracic articular processes are set on an arc so they permit rotation. The transverse processes support ribs so they have facets and are stout.

The Spinous Processes or Spines. Of the twelve thoracic spinous processes four lie above the level of the pericardium, four behind it, and four below it (*fig. 512*). The spines of those behind it (5th, 6th, 7th, and 8th) are almost vertical, and in consequence their tips lie at the level of the body of the vertebra immediately below. Those of the first two and last two (1st, 2nd, and 11th, 12th) are almost horizontal. Those of the succeeding and preceding two (3rd, 4th, and 9th, 10th) are somewhat oblique.

The Articular Processes are set almost vertically on the arc of a circle whose center is situated near the front of the body (*fig. 514*). This decides that such movements as take place between adjacent thoracic vertebrae shall be mainly rotary. The facets on the superior articular processes face postero-laterally the facets on the inferior articular processes face antero-medially.

Though the number of thoracic vertebrae equals that of the cervical and lumbar combined, the thickness of the thoracic intervertebral discs is relatively less than in either of the two other regions; so, the range of movement is limited.

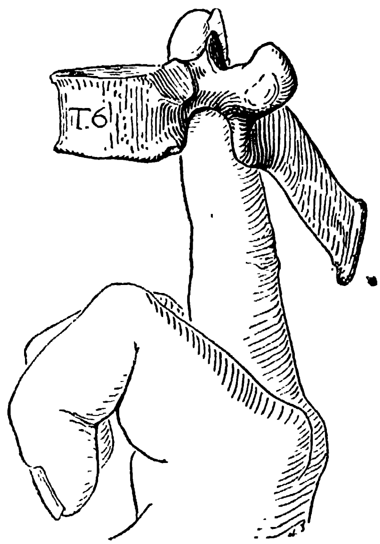


FIG. 515. A vertebral foramen is not larger than a finger-ring.

The Vertebral Foramen. Because of this restriction of movement and because the thoracic portion of the spinal cord has no enlargement but is circular on transverse section, the *vertebral foramen* is not required to be capacious: it is small and circular; you can hardly pass a finger through it (*fig. 515*). The cervical enlargement of the cord extends down to the 2nd Th. vertebra, and the lumbar enlargement begins at the 10th Th. vertebra. Accordingly, the vertebral canal in the upper two and lower two (or three)

thoracic vertebrae is somewhat triangular, as in the cervical and lumbar regions'

The inferior *vertebral notches* are large; the superior ones are absent.

As the thoracic vertebrae are followed from the middle of the series cranio-caudally, they are found gradually to assume the characteristics of cervical and lumbar vertebrae respectively. Thus:

The upper half of the first thoracic vertebra conforms to the cervical in the following respects: (a) The body has upturned sides and back -it is not flat. (b) The superior articular processes face postero-superiorly rather than postero-laterally. (c) A superior vertebral notch is present- not absent. (d) The vertebral foramen is triangular--not circular.

The lower half of the last thoracic vertebra conforms to the lumbar in the following respects: (a) The body is reniform. (b) The inferior articular processes face laterally. (c) The vertebral foramen is triangular. (d) The transverse processes carry accessory and mamillary processes.

The Sternum. The sternum or breast bone, likened to a broad-sword, is composed of 3 parts:

1. Manubrium sterni or handle.
2. Corpus sterni or body.
3. Xiphoid process or point.

The Manubrium Sterni. Three features of its upper end are noticeable in the living: (1) the very thick concave upper border called the suprasternal (jugular) notch, much deepened by: (2) the sternal ends of the clavicles, which are too large for the notches provided for them at the supero-lateral angles; and, (3) the flat tendons of the sternal heads of the Sternocleido-mastoids which cross the sterno-clavicular joints to be attached just caudal to them. To render the tendons more prominent, drop your head and press your forehead against your resisting hand.

On the side of the manubrium, immediately below the clavicular notch, there is an area for the first costal cartilage. The 1st ribs, their cartilages, and the manubrium constitute *a unit*, an ensemble, owing to the fact that the cartilages are attached to the manubrium in precisely the same manner as they are attached to their ribs—without a cavity and without ligamentous connections, that is to say

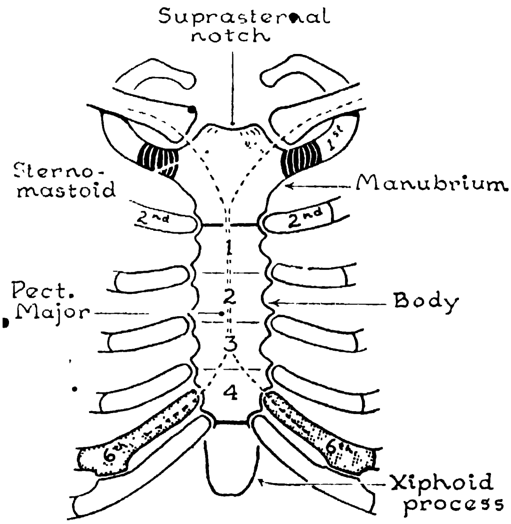


FIG. 516. The anterior surface of the sternum. · The broken lines indicate the origins of the Pectorales Majores.

they form two much elongated synchrondroses (*fig. 516*).

The *suprasternal* or *jugular notch* is one of the landmarks employed in determining the transpyloric plane. The left innominate vein on the left and the innominate artery on the right commonly peep above it.

The manubrium is 2 inches long—as long as 2 vertebrae. Its upper border lies at the level of the lower border of Th. vertebra 2, and is 2 inches from it (*fig. 517*). Its lower border articulates with the body at an angle, the *sternal*

angle of Louis. Traced laterally the transverse ridge that indicates the angle conducts the palpating fingers to the 2nd costal cartilage, the starting point from which all ribs are counted. (*Fig. 516*).

The Body of the Sternum is composed of four pieces or sternebrae, which together are slightly more than twice the length of the manubrium. In the adult, lines marking the sites of fusion of the sternebrae may be seen crossing the anterior surface of the body between angular depressions on the sides for the 3rd, 4th, and 5th rib cartilages. The 2nd rib cartilage articulates in the angular interval between body and manubrium; the 7th cartilage articulates with the lower angle of the body and the front of the xiphoid. What of the 6th cartilage? There is a special facet for it on the side of the 4th sternebra; hence, the crowding of the lower cartilages.

The medial limits of the Pectorales Majores bear much the same relationship to the anterior surface of the sternum as the lines of the reflexion of the pleurae bear to the posterior surface. Thus, from the sternoclavicular joints they converge in front of the manubrium to meet in the median plane at the sternal angle; they run together down the middle of the body, and diverge along the 6th costal cartilages. In man the two muscles merely meet in the median plane, but in birds a keel or crest projects from the sternum in order to afford the powerful wing muscles an increased surface of origin. This crest is akin to that which appears on the sagittal line of the skull of the gorilla and of some dogs to afford origin to their massive temporal muscles. Such a line is not encountered on the sterna of cursorial birds, such as the ostrich which cannot fly.

The Xiphoid Process extends downwards for a variable distance into the posterior wall of the sheath of the Rectus Abdominis. It is only half as thick as the body of the sternum, and its posterior surface is flush with the posterior surface of the body. The ends of the 7th costal cartilages lie in front of it, creating demi-facets. The xiphoid lies between the ends of the 7th costal cartilages at the bottom of the infrasternal (subcostal) angle, where it can be felt.

The tip of the xiphoid is never selected as a landmark because it is vari-

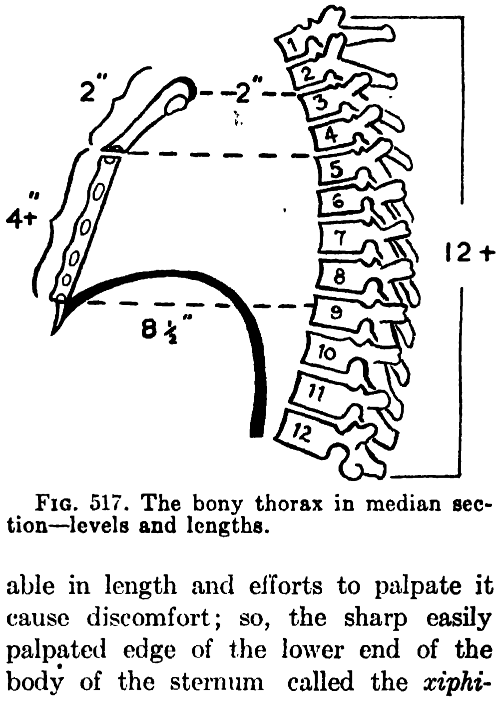


Fig. 517. The bony thorax in median section—levels and lengths.

able in length and efforts to palpate it cause discomfort; so, the sharp easily palpated edge of the lower end of the body of the sternum called the *xiphisternal joint* or *junction,* is always, preferred.

The Sterno-manubrial Joint plays an important part in the mechanism of respiration, because it allows the body of the sternum to move forwards and backwards like a door on a hinge even though the manubrium remains still. It is a replica of the symphysis pubis, and it is similar in structure to the joints between the bodies of the vertebrae.

The sterno-manubrial joint, the symphysis pubis, and the intervertebral joints lie in the median plane. They are symphyses; that is, two bony surfaces are lined with hyaline cartilage, and united by fibro-cartilage (except in the center where, through absorption, a cavity may appear), and are covered with fibrous membranes.

Synostosis of the manubrium and body of the sternum. Of 859 subjects age 20 to 90 years, synostosis occurred in about 10% of the negro males and females and of the white males; whereas it occurred in about 30% (12 out of 42) of the white females. No correlation was found between the incidence of synostosis and age. (Mildred Trotter.)

The Xiphi-sternal Joint is a synchondrosis until middle life when synostosis takes place. Bands, the ***costo-xiphoid ligaments***, pass from the 7th cartilages to the front of the xiphoid and perhaps resist the backward pull of the diaphragm, which is attached to the posterior surface. It lies at the level of the 9th vertebral body.

Common Anomalies. (a) The lower two or three sternebrae commonly ossify separately from right and left centers. Owing to lack of fusion of these a perforation, suggestive of a bullet wound, may appear in an X-ray photograph, and in the dried bone (*fig. 518*).

(b) The sterno-manubrial joint may be lacking, its place being taken by a joint between the 1st and 2nd sternebrae, as in the gibbon. The sternal angle is then situated about halfway down the sternum.

Vertebral Levels of the suprasternal notch, sternal angle, and xiphisternal joint are 2nd, 4th, 8th +.

Muscles attached to the posterior aspect: Sterno-thyroid, Sterno-hyoid to manubrium, Transversus Thoracis to body, Diaphragm to xiphoid.

Posterior Relations: Pleurae and lungs, heart and great vessels, thymus gland.

Sexual Difference: Characteristically the female sternum lies at a slightly lower level than the male. It has a relatively long manubrium and a relatively broad body.

Ossification: The manubrium ossifies from one or more centers about the 6th f. month. The sternebrae and xiphoid develop from right and left mesenchymal bars, which chondrify and fuse in the median plane. The 4 sternebrae, then, ossify from single or bilateral centers. Ossification starts—from above downwards about the 6th, 7th, 8th, and 9th f. month or later; fusion takes place from below upwards about the 15th, 20th and 25th years. The xiphoid, like the patella, starts to ossify about the 3rd year. Its synchondrosis becomes a synostosis about middle life.

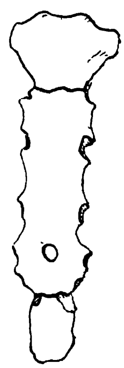


FIG. 518. A perforated sternum, the result of faulty ossification.

The Costal Arches. A rib and its cartilage constitute a costal arch. Every rib articulates posteriorly with the vertebral column, and in all there are twelve pairs of ribs. The cartilages of the upper seven pairs articulate directly with the sternum; hence, they are known as true

or *vertebro-sternal ribs.* The remaining five pairs are classified as false ribs: of these, the cartilages of three pairs (8th, 9th, and 10th) articulate with the cartilages of the ribs immediately above them and, so, form a subgroup of *vertebro-chondral ribs.* Their connection with the sternum is an indirect one. The cartilaginous ends of the last two pairs (11th and 12th) end between the muscles of the abdominal wall; hence, they form a subgroup of free, floating or *vertebral ribs.*

The sternal ends of the ribs are cartilaginous owing to the fact that ossification, which starts near the angles and spreads both forwards and backwards, fails to reach the sternal end.

Ribs are not triangular on cross-section and therefore rigid like the long bones of the limbs, but are flattened, have a very thin outer compact layer, and are highly resilient.

A Typical Rib (*fig. 519*) consists of the following parts:

1. *Body:* Internal and external surfaces; superior and inferior borders; anterior and posterior angles; and a costal (subcostal) groove. The posterior $\frac{1}{4}$ is cylindrical; the anterior $\frac{3}{4}$ is compressed.
2. *Two Ends:* (a) Vertebral—head, neck, and tubercle. (b) Sternal—pit for a costal cartilage.

With the articulated skeleton before you, confirm the following facts, because they have an important bearing on the mechanism of respiration.

1. When the costal arches (i.e., rib and cartilage) of the somewhat barrel-shaped thorax are examined in situ, the rib is seen always to take a downward slope; the cartilage generally an upward slope (*fig. 520*).

The cartilages of the first (1st) and of the last two (11th and 12th) arches, however, continue the downward inclination of their ribs; that of the 2nd is generally horizontal; the remaining cartilages (3rd–10th) are inclined upwards (*fig. 516*).

2. The sternal end of the 1st arch lies $1\frac{1}{2}$ inches lower than its vertebral end (*fig. 535*).
3. The sternal end of each arch lies at lower level than the vertebral end.
4. The middle of each arch lies at a lower level than a straight line joining its two ends (*fig. 520*).
5. The intercostal spaces are widest where rib and cartilage join.
6. Both ribs and cartilages increase in length progresssively from 1st to 7th; the seventh rib being the longest of the ribs;

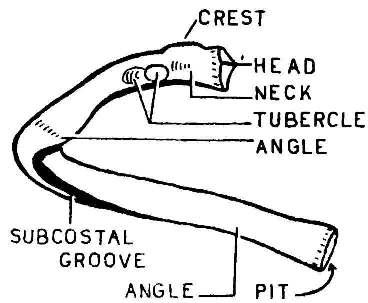


FIG. 519. A typical rib viewed from behind.

the seventh cartilage the longest of the cartilages.

7. The transverse diameter of the thorax increases progressively from 1st–8th rib, the eighth rib having the greatest lateral projection.
8. The ribs increase in obliquity progressively from 1st–9th; the ninth rib being the most obliquely placed.
9. The cartilage of the 10th rib lies at the lowest point on the thoracic wall visible or palpable from the front, though actually the tip of the 11th cartilage may be lower.
10. The anterior ends of the floating ribs (11th and 12th), not being subjected to terminal pressure, are tapering or

pointed, like the tips of the ungual phalanges of the fingers and toes and like the tip of ths coccyx. By this feature they may be distinguished.

The Articulations of the Costal Arches. In a typical articulation the head of the rib articulates with the sides of the bodies of two vertebrae; the tubercle of the rib articulates with the tip of a transverse process; and the costal cartilage articulates with the sides of two sternebrae. The articulations of a typical arch therefore are:

1. Costo-vertebral articulation:
   (a) Joint of the head of the rib.
   (b) Joint of the tubercle.
2. Costo-sternal articulation.

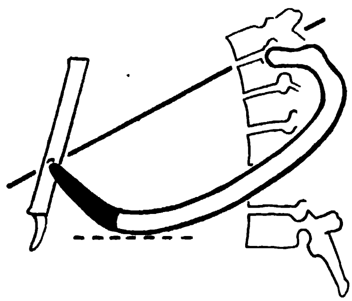


FIG. 520. A costal arch (side view).

The Heads of the Ribs and Their Articulations. The head of each rib originally articulated with the body of its own vertebra only; and the heads of ribs 11 and 12 still do. But the heads of ribs 1–10 shift cranialwards, so that ribs 2–9 practically always trespass on the vertebra next above; rib 1 does so occasionally; rib 10 does so usually (*fig. 512*). These heads, adapted to the structures with which they are in articulation, are wedge-shaped. The lower or caudal surface of the wedge remains in articulation with its own vertebra and is larger than the upper or cranial surface, which has come to articulate with the vertebra next above. The apex of this wedge, known as the *crest of the head,* is attached to the intervertebral disc by a transversely placed *intra-articular ligament.* The joints of the head have each, therefore, *two synovial cavities,* closed by a *capsule* which is strongest in front where its fibers *radiate* from the anterior margin of the head, some horizontally to the intervertebral disc, some upwards to the vertebra above, some downwards to its own vertebra. The heads of the ribs confined to single vertebrae, namely ribs (1, 10), 11, and 12, are rounded, and do not have intra-articular ligaments.

The Costo-sternal Articulations. Costal arches have been likened to bucket handles. The two ends of a bucket handle are attached to a bucket in identical fashion; and figure *521* indicates that the extreme ends of a typical costal arch are attached in almost identical fashion. Compare, then, the joint of the head of a rib with a sterno-costal joint, noting that: each end of the arch articulates in a V-shaped socket formed by the demifacets of two adjacent sternebrae or vertebrae together with the intervening cartilaginous disc. [The disc between two vertebrae is of fibro-cartilage; the disc between two sternebrae is of hyaline cartilage until synostosis is completed by the 25th year. The disc between the manubrium and corpus sterni is of fibro-cartilage.] Each end of the arch is, therefore, roughly wedge-shaped. An intra-articular ligament unites the end of the costal cartilage or the crest of the head to the corresponding disc. The joint cavity is thereby divided into two. Ligamentous fibers, known as the *radiate ligament,* radiate from the anterior margin of each extremity of the arch to two sternebrae or vertebrae, as the case may be, and to the intervening disc. The radiate ligament is but part of the capsule that completes the joint.

From the foregoing it is clear that by substituting the words "sternebra and sternebral" for the words "vertebra and vertebral" a description of the joint of a rib head becomes a description of a sterno-costal joint—but with these reservations: The 1st costal cartilage unites the first rib to the manubrium in the same manner as an epiphyseal cartilage unites an epiphysis to a diaphysis. Such a junction is a synchondrosis. The first ribs, their cartilages, and the manubrium form a single unit, which is kidney-shaped in outline. Between the five elements of this unit there is no movable joint. The 2nd cartilage articu-

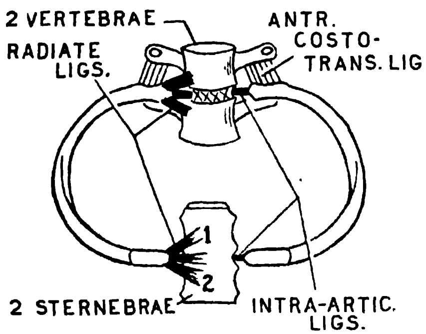


FIG. 521. The articulations of a costal arch: costo-vertebral and costo-sternal compared

lates between the side of the manubrium and 1st sternebra; the 7th cartilage between the 4th sternebra and the front of the xiphoid; the 6th cartilage with the side of the 4th sternebra.

By absorption of its intra-articular ligament a double cavity becomes single; by extension of its intra-articular ligament a joint cavity may be obliterated and a syndesmosis result. Both conditions commonly occur.

The Interchondral Articulations. The tips of the cartilages of the five pairs of false ribs are not subjected to terminal pressure; so, they are tapering. But the upper borders of the cartilages of the vertebro-chondral ribs (8th, 9th, and 10th) do come into articulation with the cartilages next above, and often do so by means of upwardly and downwardly projecting knobs. Joint cavities are present between contiguous knobs and ligamentous fibers surround them. The 7th and 6th and the 6th and 5th cartilages also commonly possess these upward thrust-transmitting knobs. The 10th costal arch is often "semifloating"—its rib not articulating with a transverse process, and its cartilage being attached to the ninth cartilage by ligamentous fibers (syndesmosis).

The Costo-transverse Articulations. *The tubercle of a rib* articulates with the facet at the tip of the transverse process

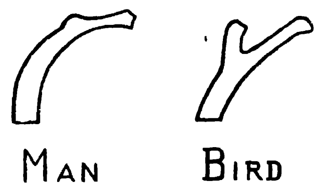


FIG. 522. The tubercle of a rib is a reduced head.

of its own vertebra. The spread of the thoracic transverse processes become progressively shorter from the first to the twelfth; so, the tubercles of the ribs become progressively closer. The 11th and 12th ribs have no tubercles; so, their necks are not defined laterally. The tubercle of a rib is morphologically a reduced head. In the bird there are two heads (*fig. 522*).

The tubercle of each vertebro-sternal rib lies at the back of its rib, is olive-shaped, and articulates with a concave facet situated on the front of the tip of a transverse process. It can rotate. The tubercle of each vertebro-chondral rib (8th, 9th, and 10th) lies near the lower border of its rib, is flat, obliquely set, and articulates with a similar facet on the

upper border of the tip of a transverse process. It can slide.

A rib is united to the transverse process with which it numerically corresponds by ligamentous fibers so-directed as to permit the rib to glide medially. This union is divided into a medial and a lateral part by the joint cavity between the tubercle and the tip of the transverse process (*fig. 523*). The *medial fibers* pass between the front of the transverse process and the back of the neck (lig. of the neck) and occupy the space which in a cervical vertebra is traversed by the vertebral artery. The *lateral fibers* pass between the tip of the transverse process and the most lateral part of the tubercle (lig. of the tubercle). Tubercles have,

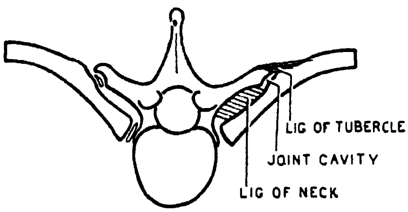


FIG. 523. Costo-transverse articulation.

therefore, a smooth medial articular portion and a rough lateral ligamentous portion. Further, from the lower border of a transverse process a band of fibers descends to the upper border of the neck of the rib next below (anterior costo-transverse lig.) often producing a pronounced flange, the *crest of the neck*. This ligament is continuous laterally with a posterior intercostal membrane.

It is at the medial border of the anterior costo-transverse ligaments that the intercostal nerves make their entrance into the thorax and that the posterior branches of the intercostal arteries make their exit. In front of these ligaments the intercostal nerves and vessels run.

Angles of the Ribs. *Posterior Angles:* A slight roughness, caused by the fibrous insertion of the Ilio-costo-cervicalis (the most lateral of the deep muscles of the back) is to be seen at the most backwardly projecting part of the outer surface of the ribs (*fig. 635*). Anterior to this the ribs are twisted downwards, forwards, and medially. Since the deep muscles of the back diminish in bulk as they ascend, it follows that the angles become progressively nearer the tubercles from below upwards till the first rib is reached. On the first rib the angle and tubercle coincide. Though the first two and the last two (1st, 2nd, and 11th, 12th) ribs have rough impressions for the Ilio-costo-cervicalis, they are scarcely twisted at all and therefore have no true angle.

Anterior Angles: Anterior to the sites of attachment of the External Oblique of the Abdomen to the lower eight ribs (about a hand's breadth from the costal margin) the ribs are bent backwards and the thorax is flattened. The angles and slight roughnesses so-produced are best marked on the middle four ribs (5, 6, 7, and 8) where the digitations of the External Oblique and Serratus Anterior interlock.

Peculiar Ribs. *The 1st Rib* is a very superlative rib, being the highest, shortest, strongest, flattest, and most curved of all the ribs. The Scalenus Anterior is attached to the Scalene tubercle of Lisfranc on its outer (upper) surface, and it separates the groove for the subclavian vein in front from the groove for the subclavian artery and lowest trunk of the brachial plexus behind. Between the latter groove and the tubercle of the rib the Scalenus Medius, Levator Costae, and first digitation of the Serratus Anterior are attached. The fascia, *Sibson's fascia*, clothing the deep surface of the

Scalenes is attached to the sharp upper (medial) border of this rib.

To the outer surface of the *1st costal cartilage* are attached: the intra-articular fibro-cartilage of the sterno-clavicular joint, the costo-clavicular ligament, and the Subclavius.

The 2nd Rib has spreading across the middle of its outer surface a large rough impression for the Serratus Anterior. The Scalenus Posterior is attached behind this.

The 10th Rib is a transitional rib, resembling either the 9th or the 11th, thus: its head may have 2 demifacets or 1 facet; its tubercle may be articular or not; its cartilage may articulate with the ninth cartilage, be connected to it by ligament, or be floating.

The 11th and 12th Ribs have large round heads, no tubercles, and pointed ends. The 11th may have a slight angle and a slight costal groove. The 12th is much shorter, and it has neither angle nor groove. To its medial half the Quadratus Lumborum is attached.

DECEPTIONS. Students and others often relate the 1st and 12th ribs to the wrong side of the body. Note that (a) The head and neck of the 1st rib: are *turned downwards* and not upwards like those of the other ribs. (b) The anterior or pleural aspect of the necks of all (save the highest) ribs look upwards as well as forwards. If the 12th rib is so-held, the side to which it belongs will be obvious.

OSSIFICATION. Like the long bones of the limbs and the bodies of the vertebrae, the ribs begin to ossify in the 2nd fetal month. Ossification begins near the angle and spreads in both directions but fails to reach the sternal end; hence, the costal cartilages. Scale-like epiphyses cap the head and tubercle.

MARROW. The vertebrae, ribs, and sternum, together with the diploë of the skull are filled with red blood-forming marrow. It is here, and not in the limb bones, that blood is formed after puberty.

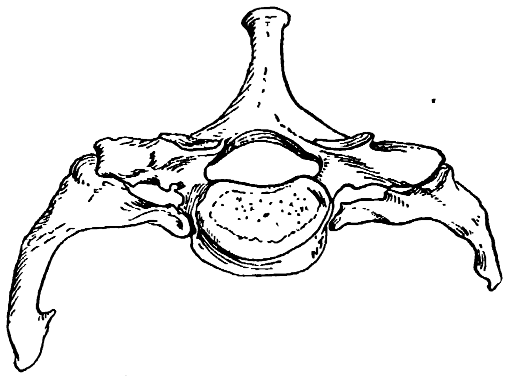


FIG. 524A. Cervical rib

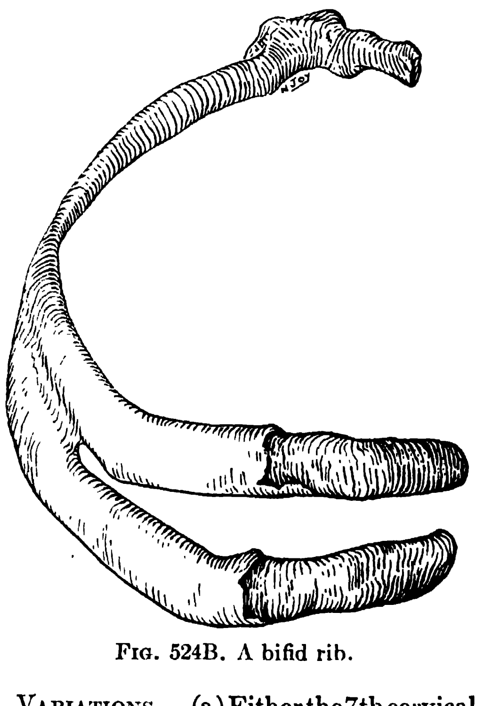


FIG. 524B. A bifid rib.

VARIATIONS. (a) Either the 7th cervical or 1st lumbar vertebra may carry a rib; in either case there are thirteen ribs.

(b) The sternal end of the 3rd or 4th rib and its cartilage are sometimes bifid (*fig. 524*).

(c) The 12th ribs are commonly so

short in the female that there are thought to be only eleven pairs of ribs.

(d) Not infrequently the 8th cartilage reaches the sternum on one or both sides; less frequently the 7th cartilage fails to reach it. As, therefore, the lowest cartilage to reach the sternum may be either the 6th, 7th, or 8th, it is not wise to count the ribs from the infrasternal angle.

(e) The head of the 1st rib commonly articulates partly with the disc between the last cervical and first thoracic vertebrae.

(f) The 10th rib may have all the characters of a vertebro-chondral rib or of a vertebral rib; usually it is transitional.

THE MECHANISM OF RESPIRATION

The two phases of respiration, *inspiration* and *expiration*, are brought about by the alternate increase and decrease in the three dimensions of the thoracic cavity. As the dimensions increase, air is drawn through the trachea and bronchi into the lungs, and blood is sucked into the thoracic veins, and thereby the formation of a vacuum is avoided. At the same time the capillaries in the lung dilate and, so, facilitate the pulmonary circulation; and any fluid in the neighborhood is encouraged into the thorax, e.g., lymph, adipose tissue, which is fluid at body temperature, the contents of an abscess.

At birth the ribs are horizontal and are, therefore, in the position of full inspiration; movement either upwards or downwards would be an expiratory act. At this age respiration is performed by the upward and downward piston-like action of the diaphragm and is said to be *abdominal in type*. By the end of the 2nd year the ribs are oblique, and by the 7th year respiration is largely performed by the ribs and is said to be *thoracic in type*.

Mechanical Factors. In the adult let the following be recalled: (a) The manubrium, the first costal cartilages, and the first ribs constitute a kidney-shaped unit, which, save for the elasticity of its cartilages, is rigid. (b) The sterno-manubrial symphysis allows of hinge-like movements. (c) The 1st–7th rib: and 1st–7th cartilages increase from above downwards in length, in degree of lateral projection, and in obliquity. (Actually the 7th is the longest of the ribs, the 8th the most laterally projecting, and the 9th the most oblique.) (d) The facets on the upper seven transverse processes for the vertebro-sternal ribs are concave and face anteriorly. The facets on the 8th, 9th, and 10th transverse processes for the vertebro-chondral ribs are flat and face antero-superiorly. The last two transverse processes have no facets, for the 11th and 12th ribs articulate only at their heads. Being free they are not required to follow the excursions either of the sternum or of the other ribs. (e) The sternal ends of the costal arches lie at a lower level than the vertebral ends; and, the middle of each arch lies at a lower level than a straight line joining its two ends (*fig. 520*).

During Quiet Inspiration the kidney-shaped unit, comprised of the manubrium and right and left 1st costal arches, remains at rest.

The Intercostals cause the 2nd–7th costal arches, each of which hangs like the handle of an inverted bucket, to rotate at the costo-vertebral joints; in consequence, their middle parts rise and their lower borders are everted. Hence, the transverse diameter of the chest increases, and the subcostal angle widens.

The Intercostals at the same time cause the sternal ends of the arches to rise; in consequence, the body of the sternum

is thrust forwards and the antero-posterior diameter of the chest increases.

The position of the facets on the transverse processes prevents the vertebro-sternal arches from being forced backwards, whereas the shape of the facets allows the rotary movement described.

Because the vertebro-sternal arches increase in length from above downwards, the lower end of the body of the sternum makes a greater excursion than the upper end, which takes part in the hinge-like sterno-manubrial articulation.

Because the movements result in longer arches rising to or towards the positions just vacated by shorter arches, the transverse and antero-posterior diameters are still further increased.

The Diaphragm and the False Arches. The anterior and lateral portions of the diaphragm are attached to the costal margin; so, they necessarily rise when the margin rises. The postero-medial portion is attached to the upper lumbar vertebral bodies, arcuate ligaments, and 12th ribs, and it is held stationary by the Quadratus Lumborum. Owing to the intra-abdominal pressure, the right and left domes of the diaphragm are rounded when relaxed, and they rise above the level of the central tendon. When on inspiration the diaphragm contracts, its fibers shorten and straighten, and thereby enlarge the phrenico-costal sinuses and cause the domes to descend. The upper abdominal viscera, especially the pliable liver, stomach, spleen, and kidneys, necessarily descend before the contracting diaphragm; and the muscles of the abdominal wall yield sufficiently to afford these viscera accommodation. Thus is the vertical diameter increased.

The three pairs of vertebro-chondral ribs (8, 9, and 10) do not imitate the movements of the vertebro-sternal ribs. Owing to the shape and position of the costo-transverse facets they cannot rotate, but they can and do glide backwards and upwards. By this movement, which resembles a pair of curved spreading calipers opening, the transverse diameter of the lower part of the thorax and upper part of the abdomen increases. When the inspiration is deep, the antero-posterior diameter of the abdomen diminishes in the median plane but increases on each side. This results in a further widening of the subcostal angle. For this, the diaphragm, acting against the resistance offered by the abdominal muscles, is responsible. It forces the upper abdominal contents laterally, and this causes the lower ribs to spread. (In an animal from which the abdominal viscera have been removed, the lower ribs are drawn inwards.) Acting against the same resistance the diaphragm also raises the lower ribs; and the interchondral knobs transmit the upward thrust to the cartilages of the true ribs.

During inspiration the intercostal spaces widen, and during expiration they diminish. The tone and elasticity of the Intercostals prevents in-sucking of the spaces: a fibrous membrane would not suffice here.

On Deeper Inspiration the movements described are amplified. The Scalene muscles raise the first and second costal arches and the sternal heads of the Sterno-mastoids raise the manubrium. Perhaps the Levatores Costarum and the Serratus Posterior Superior assist. The Serratus Posterior Inferior steadies the lower ribs.

On still deeper or forced inspiration associated with shortness of breath (whether from exertion or disease) and when sneezing and coughing, the Pectoralis Minor (perhaps also the Pectoralis Major, and Serratus Anterior) assists in elevating the ribs. For the Pec-

toralis Minor to act, the scapula must first be fixed. In the quadruped, standing on all fours, fixation is already achieved. In man the forelimbs and, therefore, the scapulae can be fixed either by: (a) finding a purchase for the upper limbs, for example by grasping the arms of a chair, or (b) by the muscular action of the Trapezius, Levator Scapulae, and Rhomboidei. These, in turn, must be fixed by the muscles of the head and neck.

The Sacro-spinalis and deep muscles of the back, by straightening the thoracic curvature, help still further to cause the ribs to open out.

The nostrils and glottis dilate rythmically to allow of easier entrance of air.

Expiration is brought about by the elastic recoil of the lungs, Transversus Abdominis, and costal cartilages. The rotation that the ribs undergo at the costo-vertebral joints during inspiration involves twisting of the costal cartilages and widening of the costo-chondral angles. It is from this twisting and widening that the cartilages recoil. This is their function; bone would not suffice here. Deep or forced expiration brings into play the Oblique Abdominal muscles, and perhaps the Ilio-costo-cervicalis and Latissimus Dorsi.

Notes: (a) The thoracic and abdominal types of respiration are usually not sharply demarcated but merge into each other, one or other type predominating. By practice and exercise the type can be modified. (b) In quiet respiration the domes of the diaphragm move about half-an-inch. The region of the i. v. cava is stationary, its opening in the central tendon is enlarged during inspiration and blood more readily enters the heart (footnote, p. 302). All the fibers of the diaphragm do not contract at one time. (c) A certain intra-abdominal pressure is necessary for the upstroke of the piston-like action of the diaphragm. This is supplied by the muscles of the anterior abdominal wall (particularly the Transversus Abdominis) and the pelvic diaphragm (Levatores Ani). (d) In expressing the contents of the hollow abdominal viscera (i.e., during micturition, defecation, vomiting, and parturition) a deep inspiration is taken and is held by closing the glottis, while the abdominal muscles and the diaphragm act in concert. (e) A sneeze and a cough are generally preceded by a deep inspiration, which is to obvious advantage.

Posture. Gravity may work with the diaphragm or against it, thus: the diaphragm rises highest and its excursion is greatest when the subject lies flat on his back with the foot of the bed raised; it is less high and the excursion is less when horizontal; still less when erect (the abdominal muscles are then antagonistic), still less when sitting down, because then the abdominal muscles are relaxed; and finally in persons whose abdominal muscles have lost their tone (e.g., cases of large umbilical herniae, visceroptosis), the diaphragm ceases to act and respiration becomes thoracic. When the subject lies (horizontally) on one side, the dome of the diaphragm of that side is higher, and makes a greater excursion, than the dome of the upper side.

Unless the head and neck are extended and fixed, the muscles that raise the pectoral girdle cannot act to advantage; in consequence, the Pectoralis Minor and other accessory muscles of inspiration that attach the girdle to the trunk cannot act. The weight of the upper limbs has then to be borne by the thorax.

Unless the thoracic region of the spine is extended, the costal arches cannot spread fully. So, with head and chin dropped, shoulders rounded, and back bent—a position that through faulty

placing of pillows a patient can easily assume—the lungs are least well aerated.

THE INTERCOSTAL SPACES

Except at the *triangle of auscultation*, which is bounded by the Trapezius, Latissimus Dorsi, and Rhomboideus Major and overlies the sixth rib and the space above it and below it (*fig. 73*), the costae are completely covered with muscles, namely: The Pectorales Major et Minor, Rectus Abdominis, Obliquus Externus Abdominis, Serratus Anterior, Latissimus Dorsi, Trapezius, Rhomboidei Major et Minor, Levator Scapulae, and the Sacrospinalis. All but two of these are flat muscles; all but three are inserted into the bones of the limb. The Serratus Anterior completely separates the scapula from the chest wall. All must be removed to obtain a complete exposure of the intercostal spaces.

The Muscles of the thoracic wall are disposed in three layers, like the flat muscles of the abdominal wall, and they have the same derivation. In both regions the nerves and vessels course between the middle and inner layers of muscles, and it is helpful to bear this consideration in mind (*fig. 525*).

Abdominal	*Thoracic*
(1) Obliquus Externus	Intercostales Externi
(2) Obliquus Internus	Intercostales Interni (antero-external)
Nerves and Vessels	
(3) Transversus	Intercostales Interni (postero-internal); Subcostalis; Transversus

The fibers of the **Intercostales Externi** run downwards and forwards between the adjacent borders of two costae. Their intercartilaginous parts, called the *anterior intercostal membranes*, are fibrous; their interosseous parts are fleshy and extend backwards to the tubercles of the ribs. The Obliquus Abdominis Externus and the Levatores Costarum overlap and blend with the Intercostales Externi in front or behind, as the case may be. These three muscles have a common direction, a common nerve supply, and a common derivation. Each *Levator Costae* arises from the tip of a transverse process and extends fanwise to the rib below; so, of the 12 pairs of Levatores Costarum the first springs from the seventh cervical vertebra; the last, from the eleventh thoracic.

The fibers of the **Intercostales Interni** run in the opposite direction and, so, cross those of the external muscles like the limbs of a St. Andrew's cross (*fig. 526*). The fleshy fibers extend from the sternal ends of the spaces to the angles of the ribs. Behind the angles, *posterior intercostal membranes* continue backwards and merge with anterior costotransverse ligaments. Each Internal Intercostal has two layers, which overlap each other near the midlateral line. The antero-external layer is attached to the outer lip of the costal groove. It belongs to the same morphological layer as the Obliquus Internus Abdominis and is continuous with it beyond the open ends of the last two intercostal spaces. The postero-internal layer is attached to the inner lip of the costal groove and belongs morphologically to the same layer as the Transversus Thoracis, Transversus Abdominis, and Subcostalis.

Subcostalis is the name given to fibers of the posterior part of an Internal Intercostal that bridge more than one intercostal space.

The Transversus Thoracis is the upward continuation of the Transversus Abdominis. It arises from the back of the xiphoid and lower two or three sternebrae and fans out to be inserted into the

third to sixth costo-chondral junctions. So, it fails to cross the upper two interchondral spaces.

Vessels. The Internal Mammary Artery (*fig. 525*) is a branch of the subclavian artery (first part). At this stage it is to be found descending a finger's breadth from the sternum, behind the Internal Intercostals and upper six costal cartilages, and dividing into its two terminal branches, the *superior epigastric* and *musculo-phrenic*.

The internal mammary artery is an intersegmental vessel, comparable to the descending aorta. Phylogenetically it is not well named, for its presence in fishes indicates that it is older than the mammals. Being the sole artery in the neighborhood, it supplies the entire neighborhood.

Branches. (1) *Perforating* (or cutaneous) *branches* perforate the Internal Intercostal, and anterior intercostal membrane, and the Pectoralis Major in the upper six spaces and supply the cutaneous structures including the mamma. The mammary branches come from the second, third, and fourth perforating branches. (2) *Anterior intercostal* (or muscular) *branches:* A large upper branch and small lower one run laterally between the vertebro-sternal ribs and cartilages. Though mainly muscular they also supply the pleura and ribs. (3) Corresponding branches of the *musculo-phrenic artery* do like service for the

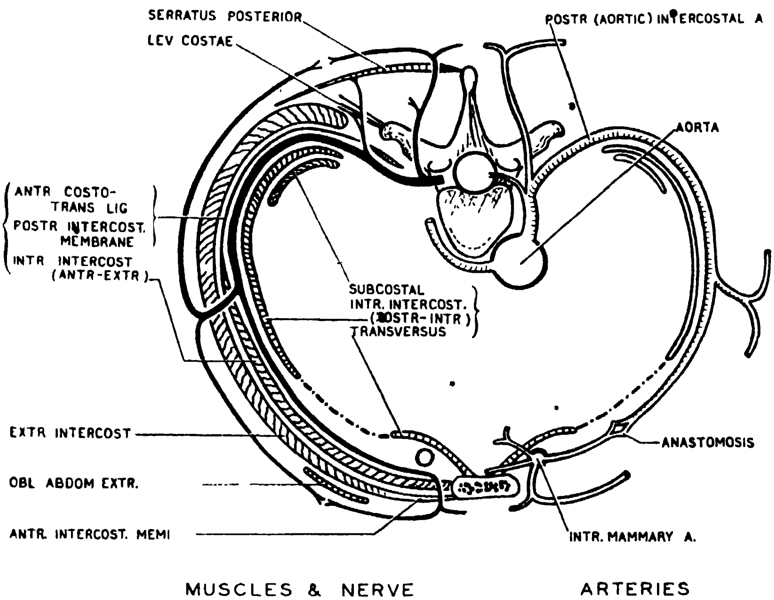


Fig. 525. The contents of an intercostal space (horizontal section).

The internal mammary a. is most readily exposed in the 1st or 2nd space, because these are the widest spaces, but here it rests directly on the pleura, which is in danger of being punctured. On this account it is safer to expose it in a lower space where the Transversus is interposed between it and the pleura.

The venae comites of the mammary artery unite and pass to the innominate vein. A lymph gland is found in most spaces.

spaces above the vertebro-chondral ribs; other branches of the musculo-phrenic artery go to the Diaphragm and to the abdominal muscles. (4) *Other twigs* supply such thoracic contents as the thymus gland, lymph glands, fat, and the pericardium, and a large branch, the *pericardiaco-phrenic,* follows the phrenic nerve. (5) The *superior epigastric artery* continues as an intersegmental vessel behind the 7th costal cartilage, and between slips of the diaphragm, into the Rectus sheath. Behind the upper part of the Rectus it anastomoses with the inferior epigastric branch of the external

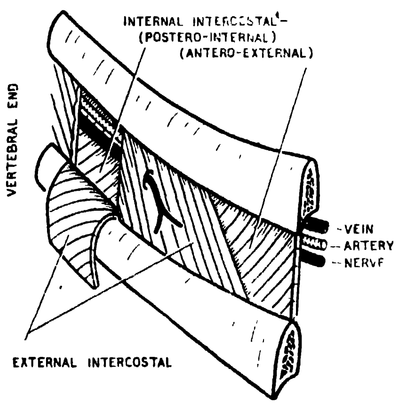


FIG. 526. The contents of an intercostal space (vertical section).

iliac artery and thereby brings the great vessels of the upper and lower limbs into communication.

A Posterior Intercostal Artery and Vein run above each nerve under the shelter of a costal groove, and, as is so generally the case with a nerve and its companion artery and vein, the artery occupies the middle position.

A posterior intercostal artery, being much larger than an anterior intercostal artery, supplies much more than half its intercostal space, and it gives off a lateral cutaneous branch, which follows a lateral cutaneous nerve.

Of the 11 posterior intercostal arteries, the upper 9 anastomose with anterior intercostal arteries derived from the internal mammary and musculo-phrenic arteries; whereas the lower 2 continue beyond the open ends of the lower two spaces into the abdominal wall.

The upper 2 posterior intercostal arteries arise from the superior intercostal artery; the lower 9 from the aorta (p. 570).

The Intercostal Nerves. Of the anterior rami of the twelve pairs of thoracic nerves, eleven are intercostal and one is subcostal. The 1st and 12th differ notably from the others: the 1st because of the very large contribution it makes to the brachial plexus; the 12th because, being subcostal, it has to run its course in the abdominal wall. The upper five of the remaining ten (2, 3, 4, 5, and 6) run typical intercostal or "*thoracic courses*"; whereas the lower five of the remaining ten (7, 8, 9, 10, and 11) run partly in the thoracic wall and partly in the abdominal wall and pursue what may be called "*thoracico-abdominal*" courses.

Let the abdominal course of a "thoracico-abdominal" nerve be recalled. A nerve (7th–11th) leaves its interspace between slips of the diaphragm, and behind an upturned costal cartilage, if there be one (spaces 10 and 11 are open in front). It then runs between the Internal Oblique and Transversus Abdominis, which conduct it to the back of the Rectus sheath. It pierces this, passes in front of the superior or inferior epigastric artery, supplies and pierces the Rectus, pierces the anterior wall of the sheath, and finally, in the company of a cutaneous branch of an epigastric artery, ends as an anterior cutaneous nerve of the abdominal wall. The 10th supplies the region of the umbilicus (*fig. 199*).

Now, in the thoracic course the same

morphological relationships are retained (*fig. 525*). Thus, a thoracic nerve (2nd–6th) lies deep to the superficial or antero-external layer of the Internal Intercostal and is separated from the pleura by the deep or postero-internal layer of the Internal Intercostal and the Transversus Thoracis; it crosses in front of the internal mammary artery and, in the company of a perforating artery, pierces the superficial part of the Internal Intercostal, anterior intercostal membrane, and Pectoralis Major to end as an anterior cutaneous nerve of the thorax. The thoracic course of nerves 7th–11th can easily be supplied.

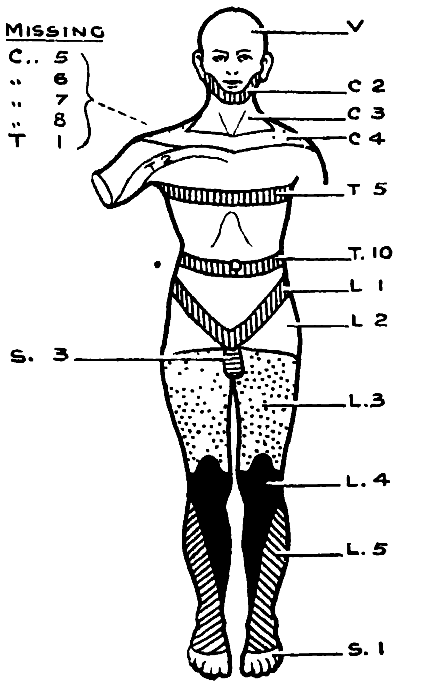


FIG. 527. Cutaneous nerve segments (from the front). (After Purves Stewart.)

The intercostal and subcostal nerves are typical, serially segmental nerves. About the midlateral line they give off lateral cutaneous branches, described with the axilla (p. 91).

SPECIAL OR IRREGULAR FEATURES OF THE NERVES. *1st intercostal nerve.* Its intercostal part is slender and motor. If it possesses lateral and anterior cutaneous branches they are trivial. It is nevertheless the largest of the thoracic anterior rami because of the large bundle it sends across the neck of the 1st rib to join the anterior ramus of C. 8 to form the lowest trunk of the brachial plexus (*fig.*

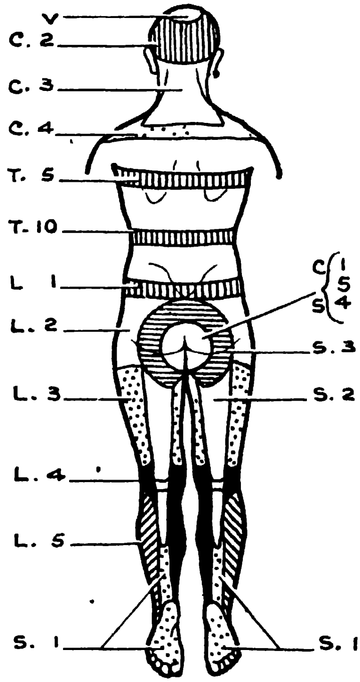


FIG. 528. Cutaneous nerve segments (from the back). (After Purves Stewart.)

548). This bundle crosses the neck of the first rib subpleurally, lateral to the superior intercostal artery. The lowest trunk of the plexus occupies the hinder part of the groove on the first rib for the subclavian artery. The subclavian vein therefore is in front, the subclavian artery is in intermediate position, and the nerve is behind.

2nd intercostal nerve. Its lateral cutaneous branch is carried subfascially

across the floor of the axilla, and subcutaneously down the postero-medial side of the arm in spiral fashion as far as the olecranon. Its anterior cutaneous branch inosculates in the pectoral region with branches of C. 3 and 4 which have descended in front of the clavicle; i.e., segments (C. 5, 6, 7, 8, and Th. 1) which go to form the brachial plexus are not represented here. (*Figs. 527, 528.*)

3rd intercostal nerve. Part of its lateral cutaneous branch reaches the medial side of the arm just beyond the axilla.

10th intercostal nerve supplies the segment about the umbilicus.

12th anterior ramus or subcostal nerve is in series with the intercostal nerves. Its lateral cutaneous branch, accompanied by the corresponding branch of L. 1 (ilio-hypogastric), crosses the iliac crest in front of the tubercle and descends to the level of the greater trochanter, as the iliac branch of Th. 12.

The muscles supplied by the intercostal and subcostal nerves are: *Thoracic:* External and Internal Intercostals, Subcostal, Transversus Thoracis, and Levatores Costarum *Abdominal:* External and Internal Oblique, Transversus, Rectus, and Pyramidalis. *Back:* Serratus Posterior Superior and Serratus Posterior Inferior.

THE PLEURAE

The Subdivisions of the Thoracic Cavity. The thoracic cavity is divided into:

1. The right and left pleural cavities.
2. The mediastinum or region between the two pleural cavities.

The contents of the mediastinum are briefly: (a) the heart within its pericardium, (b) the vessels proceeding to and from the heart, (c) the trachea, and (d) the structures in transit from neck to abdomen, such as the oesophagus, the vagus nerves, the phrenic nerves, and the thoracic duct.

The pleural, pericardial, and peritoneal cavities, as well as the cavities of the tunicae vaginales testium, are closed potential cavities lined with squamous, serous-secreting cells. In embryonic life these cavities are continuous and together make up the embryonic celom. The lung invaginates the pleural cavity in the same manner as the testis invaginates the tunica vaginalis testis.

The Pleurae. Each pleura has three parts—parietal, visceral, and connecting.

1. *The Parietal Layer.* As wall paper assumes the shape of the room it lines, so does the parietal layer of pleura. Since each room or pleural cavity is shaped like a cone bisected sagittally, it possesses two walls (costal and mediastinal), a base, and an apex (*figs. 529, 530*). The parietal layer may therefore be subdivided into: (a) The *costal pleura,* which lines the costae (i.e., ribs and their cartilages). (b) The *mediastinal pleura,* which is applied to the side of the mediastinum. (c) The *diaphragmatic pleura,* which covers most of its own half of the diaphragm. (d) The *cervical pleura* (cupola) which rises into the neck.

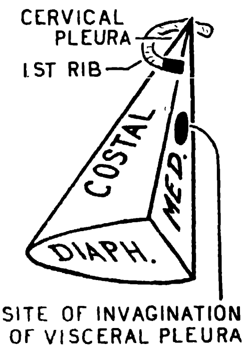


FIG. 529. **The parietal pleura as a half cone.**

2. *The Visceral Layer* or the pulmonary pleura invests the lung precisely as the peritoneum invests the liver or the spleen.

3. The connecting portion, like an *isthmus*, connects the visceral or pulmonary pleura to the mediastinal layer of parietal pleura. Actually, it is a tube or sleeve of pleura through whose upper half the structures constituting the root of the lung pass, while its lower half, being empty, is collapsed and is known as the *pulmonary ligament* (lig. pulmonale) (*fig. 531*).

Lines of Pleural Reflexion (*figs. 532, 533*). The costal pleura is continuous with (a) the mediastinal pleura in front of the vertebral column—the *vertebral*

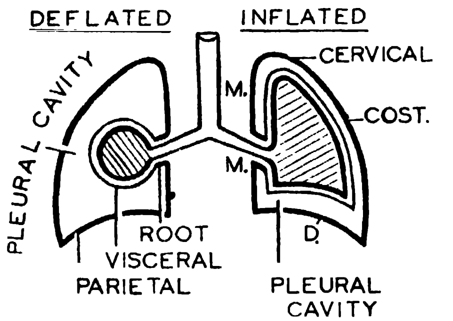


FIG. 530. The pleura: The lung represented as a balloon with a stalk. D = diaphragmatic pleura; M = mediastinal pleura.

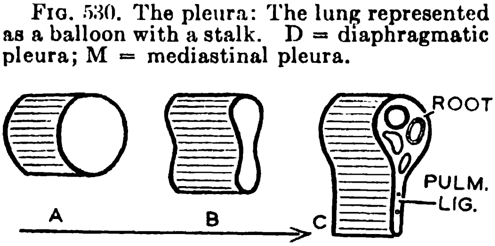


FIG. 531. Diagram of pleura at root of lung.

reflexion. (b) It is also continuous with the mediastinal pleura behind the sternum—the *sternal reflexion*. (c) And, it is continuous with the diaphragmatic pleura near the chest margin—the *costal reflexion*. The mediastinal pleura is, of course, continuous with the diaphragmatic pleura at the side of the pericardium, but because this "mediastino-diaphragmatic" line of reflexion is not near the surface of the body and has not the practical importance of the other reflexions, it is unnamed.

Because the costal layer, when traced backwards, passes on to the vertebral column to form the vertebral reflexion, and because the vertebral reflexion extends throughout the entire thoracic region from 1st to 12th thoracic vertebra, it follows that a needle, passed forwards through the posterior part of any intercostal space, must of necessity enter the pleural cavity.

The sternal and costal lines of reflexion are of high clinical importance. To plot them on the surface of the body you need tax your memory only to the extent of remembering the even numbers——2, 4, 6, 8, 10, and 12. The right and left sternal lines of reflexion pass behind the respective sterno-clavicular joints, meet each other in the median plane at (or above) the sternal angle of Louis, which lies at the level of the 2nd costal cartilages. Thereafter, the right reflexion continues downwards in the midline to the back of the xiphoid process; the left parts from the right at the level of the 4th cartilage, where it is deflected as far as (short of or beyond) the margin of the sternum, along which it is continued downwards as far as the 6th cartilage. Thereafter, as the costal reflexion, it passes obliquely across the 8th, 10th, and 12th ribs, crossing the 8th in the midclavicular line, the 10th in the midlateral line, and the 12th at its neck. The right costal reflexion likewise cuts the 8th, 10th, and 12th ribs in the midclavicular line, the midlateral line, and at the neck respectively. It differs, however, from the left costal reflexion in descending to a lower level anteriorly: for whereas the left reflexion follows the line of the 6th cartilage, the right reflexion passes from the back of the xiphoid across the xiphi-costal angle to the 7th costal cartilage.

Variations. From an investigation of 95 adult cadavera, Woodburne found that

the line of left pleural reflection in the precardial area varied from person to person especially in the 5th and 6th interspaces where there is a horizontal range of 5 cm. Indeed, 85% of reflexions lay medial to the line depicted in figure 533. Enlarged hearts seem not to effect the line.

Relationship of the Costal Reflexion to the Costal Margin. From the facts mentioned it is evident that the pleurae

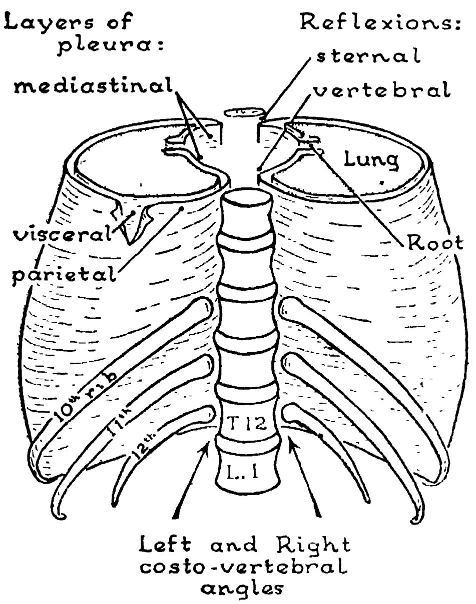


FIG. 532. The pleural reflexions, from behind.

descend below the costal margin in three regions:

(1) Right xiphi-costal angle.

(2) Right costo-vertebral angle.

(3) Left costo-vertebral angle.

In cases where the 12th rib is very short the line of reflexion comes, of course, to lie below the costal margin after crossing the 11th rib, and is therefore in surgical danger.

NOTE. Halfway round the body, that is, in the midlateral line, the costal reflexion reaches its lowest limit. At this point it is situated about two fingers breadth above the costal margin. The distance between the reflexion and the margin diminishes, so to speak, to zero or rather to subzero, as the reflexion is traced (a) backwards and upwards to the right and left costo-vertebral angles (*fig. 532*), and (b) forwards and upwards to the right xiphi-costal angle (*fig. 533*).

Below the level of the costal reflexion, the diaphragm lies in direct contact with the costae and intercostal muscles. At

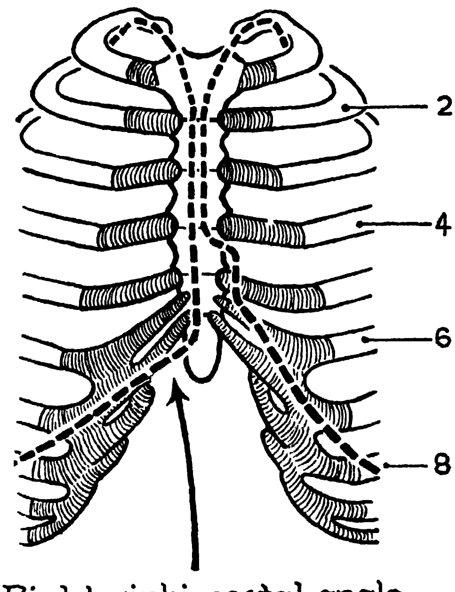


FIG. 533. Sterno-costal reflexion of pleura.

the sides and back of the chest the lower border of the lung does not descend to the level of the costal reflexion of the pleura; and, in consequence, the diaphragmatic and costal layers of parietal pleurae come into apposition with each other. The potential space unoccupied by lung is known as the *costo-diaphragmatic recess.* This recess becomes alternately smaller and larger as the lung advances into it and recedes from it during inspiration and expiration (*fig. 534*).

From these observations it follows that an instrument passed through the anterior parts of the 7, 8, 9, 10, and 11 intercostal spaces would miss the pleural cavity but would penetrate intercostal muscles, diaphragm, and enter the peritoneal cavity. At a slightly higher level it would penetrate intercostal muscles, costo-diaphragmatic recess, diaphragm and enter the peritoneal cavity. Still higher it would penetrate the lung also.

The only other region of the pleural cavity not occupied by lung lies at the anterior ends of the 4th and 5th left interspaces. Here, owing to a deficiency

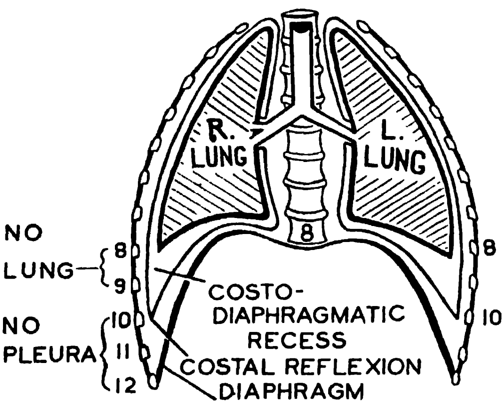


FIG. 534. Coronal section of thorax (semi-schematic).

in the anterior border of the left lung, where it overlies the heart, and hence called the *cardiac notch of the lung*, the costal and mediastinal layers of the left pleura come into direct contact with each other and form the *costo-mediastinal recess.* Thus, there are three pleural recesses:

(1) Right costo-diaphragmatic recess.
(2) Left costo-diaphragmatic recess.
(3) Left costo-mediastinal recess.

Does the apex or cupola of the pleura rise above the level of the 1st rib? The answer "Yes" and the answer "No" are alike incorrect. The cupola rises to, but not above, the neck of the first rib, which therefore protects it from injury from behind. But, since there is a drop of an inch and a half between the vertebral and sternal ends of the first rib, it follows that the pleura rises 1½ inches above the sternal end. Here the clavicle offers some protection (*fig. 535*).

When the pleural cavities have been opened, you should not fail to verify (or modify) the foregoing all-important statements regarding the limits of the pleura.

Notice whether a sharp, straight probe passed horizontally at the following points enters or misses the pleural cavity: *below the chest margin* at the right xiphicostal angle, and at the right and left costo-vertebral angles; *above the neck*

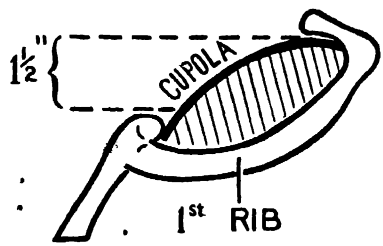


FIG. 535. Cervical pleura or cupola.

of the 1st rib on both sides; at the *anterior ends of the 4th, 5th, and 6th* left interspaces; at the *8th rib* in the midclavicular line and the *10th rib* in the midlateral line on both sides; and below the *6th left costal* cartilage.

The Mediastinum, being the region between the right and left pleural cavities, is covered on both sides with mediastinal pleura (*fig. 532*). The mediastinal pleura extend from the sternum in front to the bodies of the twelve thoracic vertebrae behind; and from the diaphragm below to the thoracic inlet above.

It will be recalled that the ribs are set not horizontally but obliquely, there being a drop of an inch and a half between the vertebral and sternal ends of the first

ribs. Accordingly, the suprasternal notch or upper end of the sternum lies not at the level of the 1st thoracic vertebra but $1\frac{1}{2}$ inches lower—at the level of the disc between the 2nd and 3rd. The obliquely set manubrium sterni is about as long as the bodies of two vertebrae and the intervening disc (i.e., 2 inches). The more perpendicularly set corpus sterni, being more than twice the length of the manubrium, is longer than four vertebral bodies and intervening discs. Thus, the sternal angle lies a little below the body of the 4th vertebra; the xiphisternal joint well below the 8th vertebra (*fig. 517*).

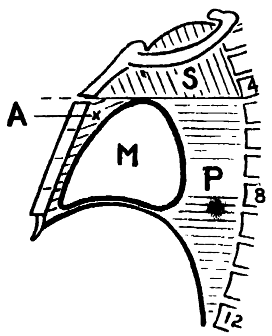


FIG. 536. Subdivisions of the mediastinum.

SUBDIVISIONS. The central and most vital structure within the mediastinum is the heart. It is contained within a fibrous sac, the *fibrous pericardium.* The areas above, in front of, and behind the pericardium are known respectively as the superior, anterior, and posterior mediastina, while the area *within* the pericardium is referred to as the middle mediastinum. In man, who walks erect, but not in quadrupeds, the fibrous pericardial sac is fused below with the central tendon of the diaphragm; above, it reaches to the level of the sternal angle. In fact, it happens to be co-extensive in the median plane with the body of the sternum, perhaps overstepping it slightly at the upper and lower ends; so, one may say—in front of the pericardium are the 4 sternebrae that comprise the body of the sternum; behind it are the middle 4 thoracic vertebrae (*fig. 536*).

The *superior mediastinum* is the subdivision of the mediastinum above the level of the fibrous pericardium. This is equivalent to saying the region above the plane joining the sternal angle to the intervertebral disc between the 4th and 5th thoracic vertebrae. The *anterior mediastinum* is the small area in front of the pericardium where the sternal reflexion of the left pleura fails to meet the right pleura in the median plane (*fig. 533*). It is evident from what has been said that it is situated dorsal to the portion of the left half of the sternum that lies caudal to the 4th cartilage and that it may include the sternal ends of the (4th), 5th and 6th left intercostal spaces. It has no contents save a little fat and some lymph glands. The *posterior mediastinum* lies behind the pericardium and also extends downwards below its level. In fact, the lower 8 thoracic vertebrae bound it behind; the pericardium and diaphragm bound it in front. The *middle mediastinum*, of which the fibrous pericardium is practically the envelope, contains not only the heart but also the roots of the eight great vessels passing to and from the heart. Lateral to the pericardium on each side run the phrenic nerves and their companion vessels, the pericardiaco-phrenic vessels. They are the sole contents of what might be described as the "lateral mediastinum". But, as no such region is recognized, they are usually described with the middle mediastinum. The anterior, middle, and posterior mediastina may be referred to collectively as the *inferior mediastinum.*

On or about the almost horizontal plane that separates the superior medias-

tinum above from the inferior mediastinum below, many structures will in due course be seen to end, or to begin, or to arch, or to bend. Hence, it is a critical level.

The mediastinal pleurae cannot be studied satisfactorily until the lungs have been removed. *To remove a lung* it is necessary to sever its root and the empty fold of pleura, the pulmonary ligament, that descends from the root. Before doing so, observe that just as a finger can be passed over the rounded upper border of the root of the lung, so it can be passed under the sharp lower border of the pulmonary ligament. The phrenic nerve and its companion vessels course medial to the mediastinal pleura half an inch in front of the root, and, so, need not be touched. Branches of the vagus nerve join behind the root with branches from the 2, 3, and 4 sympathetic ganglia to form the *posterior pulmonary plexus.* They should be identified before being cut. The detached lung should be put aside until the study of the parietal pleura is completed.

The Mediastinal Pleurae. The structures covered by the right and left sheets of mediastinal pleura are readily displayed because there is but little fat within the thorax. Their relative positions should be noted with considerable care; and, for reasons which will become apparent, they should be considered under the groupings given below, and not haphazard. It is wise to sketch them in a blank form, which from the information already supplied can easily be outlined.

The thoracic contents were originally disposed symmetrically on the two sides of the body, but this initial symmetry was early lost, largely in consequence of the disappearance of certain veins from the left side and of certain arteries from the right, as explained on page 555. The right side is the simpler; so, it will be examined first.

The Right Mediastinal Pleura. On the right side investigate the structures in the following order:

1. Pericardial sac.
2. Two sites devoid of mediastinal contents.
3. Inferior vena cava (I. V. C.)
   Superior vena cava (S. V. C.)
   Right innominate vein
   Right jugular vein
   Right subclavian vein
   Right phrenic nerve
4. Oesophagus and Trachea: Right vagus nerve.
5. Root of lung and pulmonary ligament: Bronchus, Pulmonary artery, Pulmonary veins, and Vessels and Nerves.
6. Arch of the azygos vein.

The Pericardial Sac encloses the middle mediastinal contents[1] and is co-extensive in the median plane with the body of the sternum. It is separated from the right half of the body of the sternum by the thickness (or rather thinness) of the anterior border of the right lung and pleura. The sac is separated from the middle four thoracic vertebrae by the thickness of the aorta and the collapsed oesophagus (*fig. 537*).

Two Sites Devoid of Contents. In two places the mediastinum has no contents; so, the right and left layers of mediastinal pleura come into apposition: (1) between the sternum and pericardium from the level of the second to the fourth costal cartilages, and (2) between the lower end of the oesophagus and the aorta. Here the two layers form a dorsal *meso-oesophagus.* Place a hand in each pleural cavity and feel these thin partitions;

[1] Exclusive of the phrenic nerves and their accompanying vessels.

inspect them also. If either were to break down the result would be a single common pleural cavity (*fig. 547*).

The Venae Cavae and the Right Phrenic Nerve. A pliable wicker stick passed upwards through the cut abdominal end of the i. v. cava will enter and traverse the right atrium (unless it is filled with hardened blood clot), and if pushed onwards will traverse the s. v. cava and the right innominate vein, and if continued

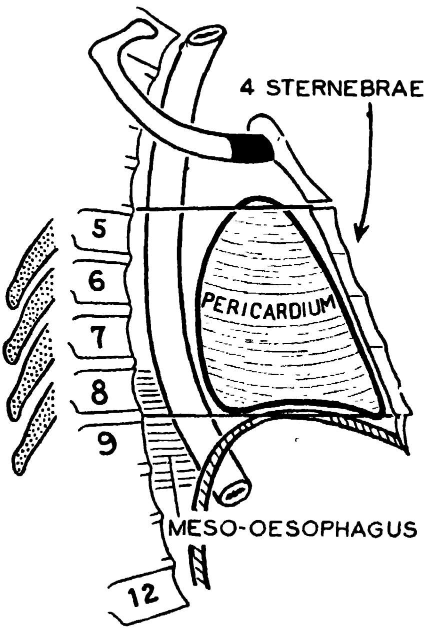


FIG. 537. The pericardial sac has 4 sternebrae in front of it and 4 vertebrae behind.

upwards into the neck will enter the internal jugular vein. Palpate the stick and note that the venae cavae enter the pericardium and debouch into the right atrium on a plane anterior to the root of the lung and pulmonary ligament. These veins may be likened to two rivers that flow due north and south to empty into a lake, the *right atrium* (*fig. 538*).

On each side of the body the internal jugular and subclavian veins unite behind the sterno-clavicular joint to form the corresponding innominate vein. The left innominate vein crosses behind the upper half of the manubrium and joins the right innominate vein at the right margin of the sternum to form the s. v. cava. The s. v. cava descends from the 1st to the 3rd right costal cartilage and there opens into the right atrium. Its upper half is outside the pericardial sac; its lower half is inside. The i. v. cava, which likewise is partly outside and partly inside the pericardial sac, pierces the diaphragm and enters the heart at

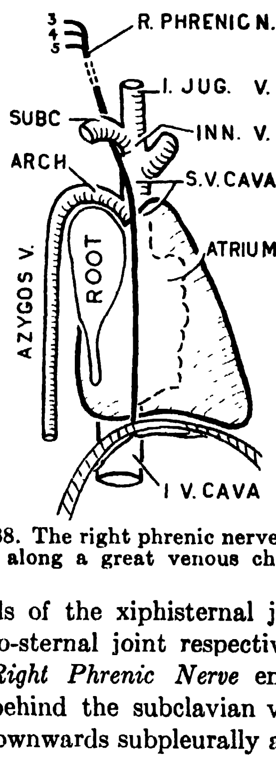


FIG. 538. The right phrenic nerve runs subpleurally along a great venous channel.

the levels of the xiphisternal joint and 6th costo-sternal joint respectively.

The Right Phrenic Nerve enters the thorax behind the subclavian vein, and passes downwards subpleurally along the line of the wicker stick that traverses the great venous channel mentioned in the preceding paragraph; that is, it lies in contact with the right side of the right innominate vein, superior vena cava, pericardium, and inferior vena cava—the pericardium separating it from the lower part of the s. v. cava, right atrium, and upper part of the i. v. cava. It then

pierces the diaphragm and spreads out on its abdominal surface. It is the sole motor supply of the right half of the diaphragm. Entering the thorax be-between the subclavian artery and vein, it crosses (either in front of or behind) the internal mammary artery and from it acquires a companion, the *pericardiacophrenic artery*. In its course it passes in front of the root of the lung and sends sensory twigs to the pericardium and pleura. It is, therefore, a mixed nerve. Twigs are said to reach the liver and the adrenal gland.

Oesophagus, Trachea, and Right Vagus Nerve. A fish has neither lungs, bronchi, nor trachea; so, its stomach occupies a much more cephalic position than in a

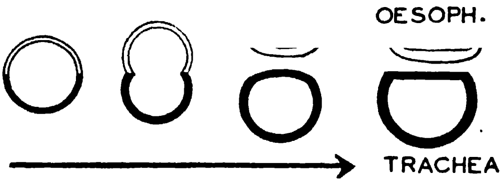


FIG. 539. The primitive food passage becomes the oesophagus and trachea.

mammal. Its oesophagus is merely a sphincter separating its stomodeum from its stomach: it has no length. The nerve supply to this sphincter and stomach is the vagus, the vagrant or wandering nerve. In man (and mammals) lungs, bronchi, and a trachea make their appearance as an outgrowth from the upper part of the food passage and, therefore, the vagus nerves, being the nerves of the food passage, are called upon to supply them (*fig. 539*). The vagus nerves may now appropriately be called the pneumogastric nerves, a term that would indicate that they supply the air apparatus and food apparatus. These remarks are designed to make clear two points: (1) that the trachea is entitled to lie in direct contact with the oesophagus throughout its entire course—save for the small amount of areolar tissue requisite to allow each to enlarge and contract independently of the other; and (2) that the right vagus is to be sought in direct contact with either the trachea or the oesophagus. In point of fact, the right vagus, after entering the thorax between the subclavian artery and innominate vein, passes obliquely downwards and backwards first on the side of the innominate artery, then on the side of the trachea to the back of the root of the

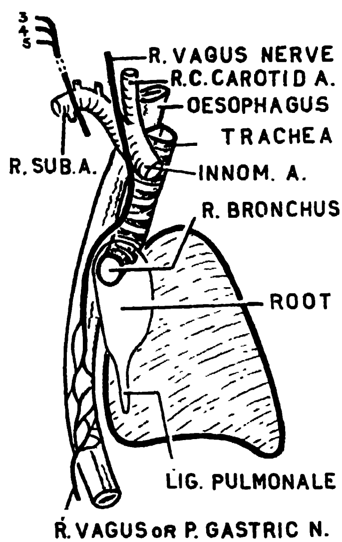


FIG. 540. The right vagus nerve is applied to the trachea and oesophagus.

lung where it takes part in the posterior pulmonary plexus (*fig. 540*). From this plexus the main trunk then passes to the oesophagus and adheres to it thereafter.

The oesophagus lies in front of the vertebral column except below, where the aorta gains the middle line and interposes itself. The trachea lies immediately in front of the oesophagus throughout the superior mediastinum, and on reaching the plane between the superior and posterior mediastina it bifurcates into a right and a left bronchus.

The Root of the Lung and the Pulmonary Ligament. The three essential structures in the root of the right and left lungs are:

1. The pulmonary artery which brings blood, charged with carbon dioxide and blue in color, from the heart to the lungs.

2. The pulmonary veins (there are two on each side, an upper and a lower) which return oxygenated blood, red in color, to the heart.

3. The bronchus or air passage, which can be identified by the cartilage in its wall.

As in the root of the lung no rearrangement of structures takes place, it follows that the bronchus, which has common derivation with the oesophagus, lies posterior to the vessels which are passing to and from the heart. Of the vessels, the two pulmonary veins of each side pierce the pericardium to end in the left atrium and are, therefore, below the corresponding right or left pulmonary artery, which lies along the upper border of the atria, as will be appreciated when the heart is studied (*fig. 568*). The order is the same on both sides, namely: bronchus behind, artery above, veins below (*fig. 542*). On the right side there is an additional bronchus—the bronchus to the upper lobe of the lung; and, because it is higher even than the artery, it is called the *eparterial bronchus*. These structures occupy the upper part of the sleeve of pleura that connects the pulmonary pleura to the mediastinal pleura. Because the lower part of the sleeve is traversed only by a few lymph vessels, it is collapsed; its anterior and posterior walls are applied to each other and form the *pulmonary ligament* (lig. pulmonale). The root springs from the mediastinum where its constituents assemble—the bronchus at the upper and front part of the posterior mediastinum; the vessels near the back of the pericardium.

Also in the root of the lung are:

4. Nerve plexuses.

5. Bronchial vessels.

6. Lymph glands.

The vagus has been seen to form a plexus behind the root of each lung, and joining it are branches from the sympathetic cord (segments 2, 3, and 4). From this *posterior pulmonary plexus* branches proceed into the lung. Some fibers from the vagus pass to the front of the root where, with others from the cardiac plexus, they constitute the *anterior pulmonary plexus*. From it, fibers enter the lung.

The lung stroma derives pure arterial blood from the *bronchial artery*, much as the liver stroma derives pure arterial blood from the hepatic artery. The bronchial arteries spring from the aorta or from an intercostal artery and run with the bronchi.

In the root of the lung there are many *lymph glands*, black from inhaled pigment.

The Arch of the Azygos Vein. The azygos vein runs upwards in front of the vertebral column to the junction of the posterior and superior mediastina and there arches forwards above the root of the lung to end in the s. v. cava before the latter pierces the pericardium. The arch crosses lateral to the oesophagus, trachea, and right vagus.

Throughout its entire thoracic course the oesophagus is clothed on its right side with mediastinal pleura, save only where the azygos arch crosses it above the root of the lung. Pass a wicker stick through the esophagus, palpate it and satisfy yourself of this.

In due time it will be seen that the innominate artery, the right end of the left innominate vein, the beginning of the

aortic arch, and thymus gland are also in contact with the right mediastinal pleura.

The Left Mediastinal Pleura. The structures covered by the left mediastinal pleura should now be identified, and investigated under the following groupings, and sketched in a blank form:

1. Pericardial sac.
2. Root of left lung and pulmonary ligament.
3. Aortic arch and descending thoracic aorta.

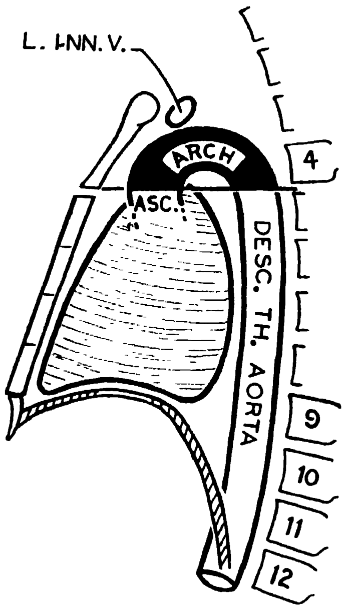


FIG. 541. The thoracic aorta.

4. Oesophagus, trachea, left recurrent nerve, and thoracic duct.
5. Left carotid and subclavian arteries.
6. Left phrenic and vagus nerves and left superior intercostal vein.
7. Oesophagus.

The Pericardial Sac, the *Root of the Left Lung*, and the *Pulmonary Ligament* are disposed as on the right side. It will, however, be noted that (a) two-thirds of the pericardium lie on the left of the median plane; that (b) owing to deficiencies in the anterior border of the left lung and pleura—hence the anterior mediastinum—the pericardium comes into direct contact with the left half of the body of the sternum below the level of the 4th costal cartilage; and that (c) as there is no eparterial bronchus on the left side, the left pulmonary artery is the highest structure in the root of the left lung.

The Aortic Arch (*fig. 541*) is the portion of the aorta lying in the superior mediastinum. It begins where the ascending aorta leaves the pericardium, which is at the level of the sternal angle. It arches backwards and to the left above the root of the left lung, rising half way up the manubrium sterni and reaching the vertebral column at the lower border of the 4th thoracic vertebra. Thereafter, as the *descending thoracic aorta*, it traverses the posterior mediastinum in contact with the bodies of the lower eight vertebrae, first on their left side, but gradually gaining the middle line. Finally, at the disc between the last thoracic and the first lumbar vertebra, it passes behind the median arcuate ligament of the diaphragm to become the abdominal aorta.

The Trachea and Oesophagus (*figs. 542, 543*). In the superior mediastinum these are seen to lie in front of the vertebral column, just as they do on the right side. The oesophagus, however, projects to the left distinctly beyond the edge of the trachea. In the angle between the trachea and oesophagus runs the *left recurrent laryngeal nerve*. On the side of the oesophagus, the thin walled *thoracic duct* ascends embedded in a film of fat. As these four structures run parallel and together, like a bundle of sticks, they should be thought of collectively and regarded as a "unit". The aortic arch crosses not only one of them, but all four.

The Left Common Carotid and Left Subclavian Arteries (*fig. 544*) arise from the convexity of the aortic arch, where it crosses the trachea, and pass obliquely upwards and backwards in semispiral fashion round the "*unit*", and therefore cross in turn the trachea, recurrent nerve, oesophagus, and thoracic duct. At a

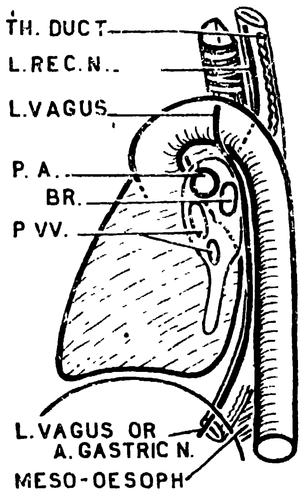


FIG. 542. The trachea and oesophagus seen from the left side.

FIG. 543. Four parallel structures—"a unit" (transverse section).

higher level the duct passes behind the common carotid artery and the other contents of the carotid sheath.

The Left Phrenic Nerve (*fig. 545*) enters the thorax between the subclavian artery and vein (at the beginning of the innominate vein), and runs a subpleural course, being covered throughout with mediastinal pleura. It crosses either anterior or posterior to the internal mammary artery, passes in front of the root of the lung, and is the sole motor nerve to its own half of the diaphragm.

Now, in the foregoing respects the left nerve is identical with the right. In the following respects it differs: The left nerve descends on the side of the common carotid artery, which conducts it to the aortic arch; this it crosses anterior to the vagus nerve. Thereafter, it is applied to the left side of the pericardium, which separates it from the stem of

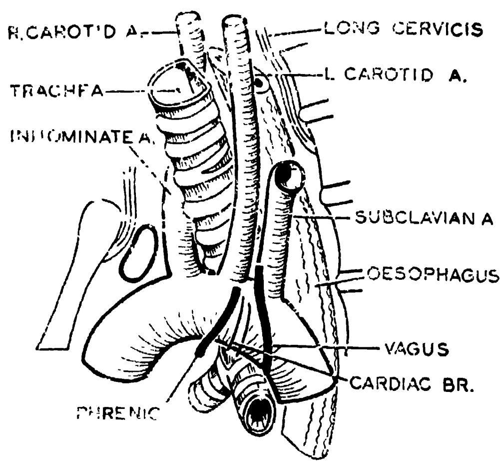


FIG. 544. Arteries ascend the "unit" in semispiral fashion.

the pulmonary artery, the left atrium, and left ventricle.

The Left Vagus Nerve, after traversing the neck within the carotid sheath on the lateral side of the carotid artery, continues through the superior mediastinum on the lateral side of the same artery, and, therefore, between it and the subclavian artery. These two arteries conduct it to the aortic arch which it crosses to gain the back of the root of the lung. Thereafter, it passes to the oesophagus and behaves like the right vagus.

The Left Recurrent Laryngeal Nerve springs from the vagus where the latter

crosses the left side of the aortic arch. It then passes below the arch and up on its right or medial side to gain the interval between the trachea and oesophagus where it has already been studied (*fig. 597*).

It is preferable to speak of the left recurrent laryngeal nerve as taking a recurrent course around the ligamentum the (left) pulmonary artery to the (left) aortic arch. The brain, head, neck, and upper limbs were thereby assured of the purest blood, because the ductus discharged into the aorta beyond the origin of the left subclavian artery. The aortic end of the ligamentum arteriosum is, therefore, to be sought just beyond the

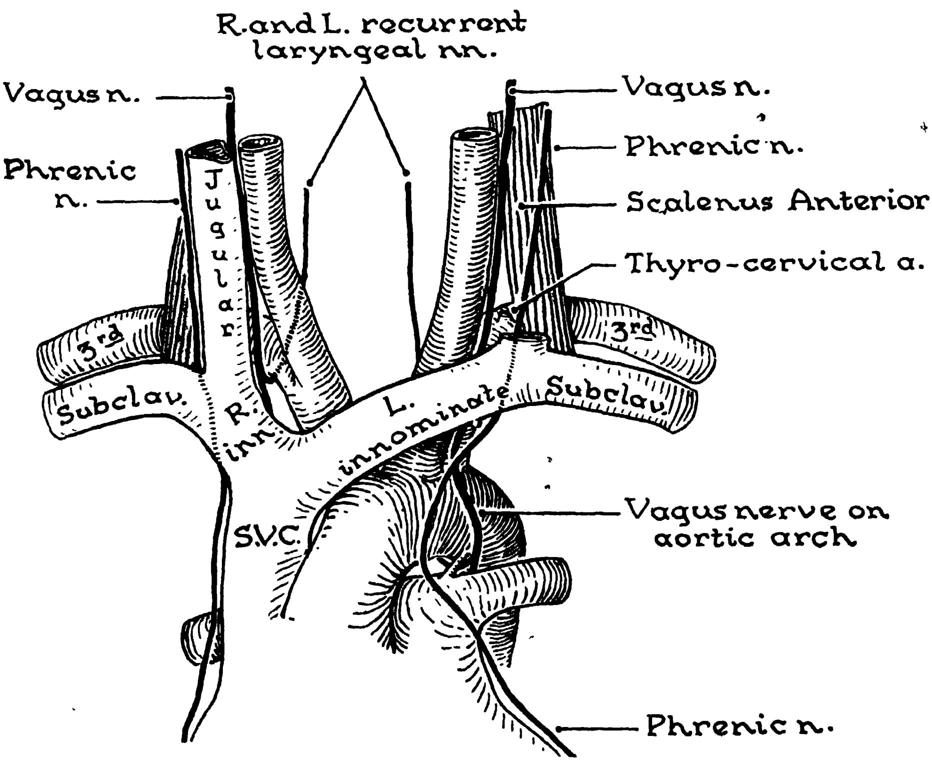


FIG. 545. The courses of the phrenic and vagus nerves.

arteriosum rather than around the aortic arch. The *ligamentum arteriosum* is the obliterated posterior half of the primitive VI left aortic arch; the beginning of the left pulmonary artery being its ventral half (*fig. 592*). In fetal life the ligamentum arteriosum was a patent vessel, the *ductus arteriosus*. Its duty was to exclude or partially to exclude the functionless lungs from the circulation by "short-circuiting" the impure blood from origin of the left subclavian artery, on the concave side of the arch.

Two cardiac nerves arising in the neck, one from the vagus the other from the sympathetic trunk, cross the aortic arch between the left phrenic nerve in front the left vagus behind (*fig. 544*), and join the *superficial cardiac plexus*, which lies on the immediate right of the ligamentum arteriosum.

The Left Superior Intercostal Vein, being

in part the equivalent on the left side of the body of the arch of the azygos vein on the right side, passes lateral to the vagus nerve and medial to the phrenic nerve as they cross the aortic arch. It drains the 2nd, 3rd, and 4th left intercostal veins into the left innominate vein. Its embryological value is given in figure 579.

The Oesophagus. In the upper half of the posterior mediastinum, the left side of the oesophagus is concealed by the descending thoracic aorta. In the lower half, the oesophagus crosses the aorta to gain the left side of the thorax and is clothed with left mediastinal pleura as far as the level of the 10th thoracic vertebra where it pierces the diaphragm (*fig. 546*).

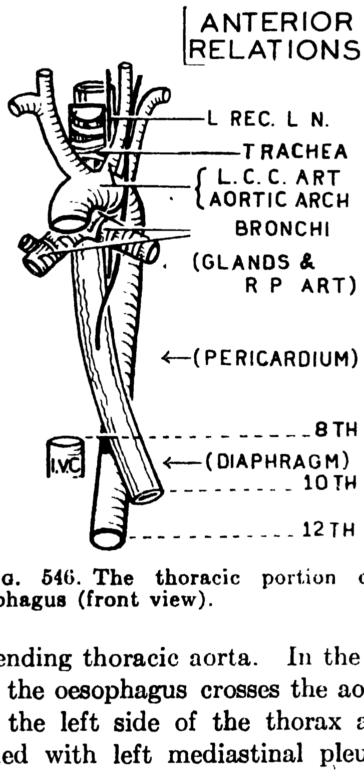


FIG. 546. The thoracic portion of the oesophagus (front view).

Does the oesophagus cross ventral or dorsal to the aorta? The answer is, "ventral". The explanation, which is embryological and simple, is given in figure 593. As this is fundamental, you must not fail to appreciate it. You might argue that since the stomach and intestines lie ventral to the descending abdominal aorta, the oesophagus, which is the upward continuation of the stomach, should be found ventral to the descending thoracic aorta; or again, if the i. v. cava pierces the diaphragm at the level of the 8th vertebra, the oesophagus at the 10th, and the aorta at the 12th, then, owing to the shape of the diaphragm, the i. v. cava should lie on a plane ventral to the oesophagus, and the oesophagus on a plane ventral to the aorta. But the most cogent and convincing argument is the embryological one.

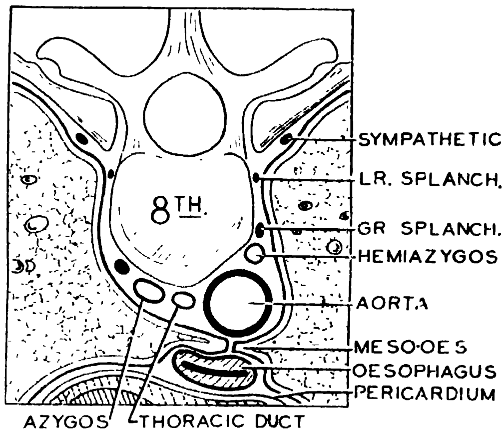


FIG. 547. Transverse section through posterior mediastinum, showing meso-oesophagus and general relations.

Pass a wicker stick through the oesophagus, to render palpation more easy, and note its relations (1) to arteries and (2) to pleura: (1) Several arteries intervene between the oesophagus and the left mediastinal pleura: they are the left common carotid artery, the left subclavian artery, the aortic arch, and the descending thoracic aorta. (2) The left mediastinal pleura is in contact with the oesophagus at two sites, (a) in the angle between the aortic arch and the left subclavian artery, though even here the

thoracic duct intervenes; and, (b) in the lowest part of its thoracic course. Here it is attached to the front of the aorta by a *meso-oesophagus*, formed by the meeting of the right and left sheets of mediastinal pleura (*fig. 547*). With a hand in each pleural cavity, let the fingers meet behind the oesophagus, and satisfy yourself of this. This meso-oesophagus commonly extends much further cranially, thereby allowing the oesophagus to advance several cm. from the vertebral column. The lungs then approach each other behind the oesophagus, particularly on inspiration and with the subject erect. A lateral X-ray picture reveals this *retro-oesophageal space*.

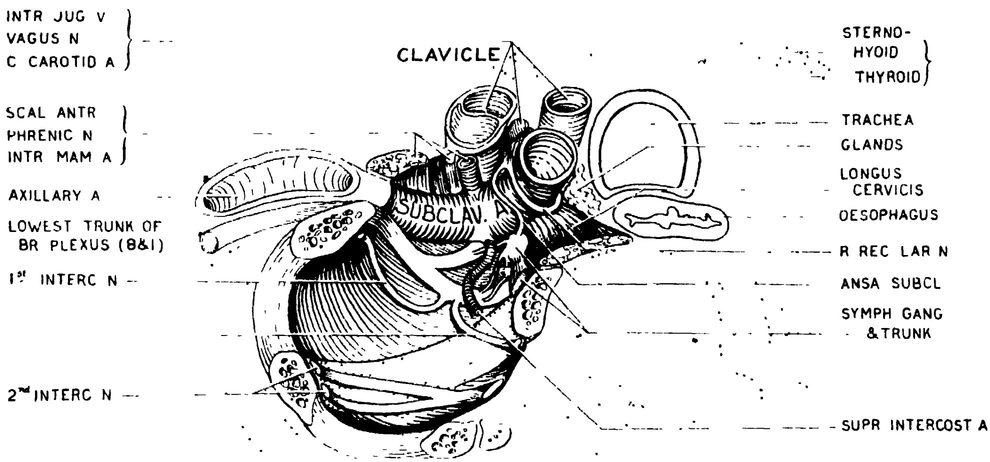


FIG. 548. The cervical pleura has been removed in order to display its immediate relations. (Viewed from below.)

The Cervical Pleura (*fig. 548*) (apical pleura, cupola, or dome of the pleura) rises to the neck of the first rib, which is an inch and a half above the sternal end of the first costal cartilage. It forms both the cupola of the pleural cavity and the floor of the root of the neck (*fig. 680*). Instead of intercostal muscles it is protected externally by scalene muscles which are lined internally with a dense areolar membrane (Sibson's fascia). The *subclavian artery* crosses the cupola, divides it into an anterior and a posterior area, and disappears between the Scalenus Anterior and Scalenus Medius. Of its four branches, three are seen, namely, the *internal mammary artery* passing downwards and forwards, the *superior intercostal branch* of the costocervical trunk passing downwards and backwards, and the *vertebral artery* ascending. The union of the *subclavian* and *internal jugular veins* to form the innominate vein takes place on the cupola at the medial border of the Scalenus Anterior. From this point the *right innominate vein* descends vertically somewhat in front of the *innominate artery*.

Crossing the neck of the first rib subpleurally are the *superior intercostal artery*, with the *sympathetic trunk* medially and the branch of the anterior ramus of the *first thoracic nerve* to the brachial plexus laterally. The superior intercostal artery supplies the first two intercostal spaces from behind. The first thoracic sympathetic ganglion is large and lies behind the vertebral artery. A

small twig, the *ansa subblavii*, passes in front of the subclavian artery to join the lowest cervical ganglion

The *phrenic nerve* enters the thorax between the subclavian artery and innominate vein, and descends subpleurally: the right phrenic—on the side of the great vein; the left phrenic—on the side of the carotid artery. The *right vagus* enters the thorax medial to the phrenic nerve, between the same artery and vein, and here gives off the *right re-*

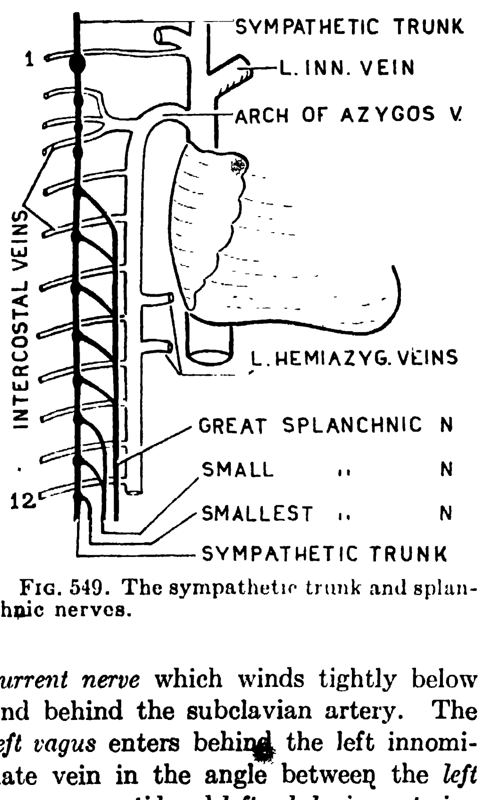


FIG. 549. The sympathetic trunk and splanchnic nerves.

current nerve which winds tightly below and behind the subclavian artery. The *left vagus* enters behind the left innominate vein in the angle between the *left common carotid* and *left subclavian arteries.* It passes behind the phrenic nerve, but is at some distance from it.

The Sympathetic Trunk (*figs. 547, 549*). The thoracic portion of the sympathetic trunk is covered throughout with costal pleura, nothing intervening, and it lies a little wide of the mediastinum. Nevertheless, *it is well to consider* it now, before its branches to mediastinal structures are destroyed.

The sympathetic trunk extends from the base of the skull above, where fibers accompany the internal carotid artery through the carotid canal, to the coccyx below, where it joins its fellow of the opposite side in the ganglion impar. Traced caudally, the trunks of the two sides become progressively closer together. At the thoracic inlet each trunk lies medial to the superior intercostal artery. In the thorax each trunk crosses successively the neck of the first rib, the heads of the 2nd–9th ribs, the 10th costo-vertebral joint, and the bodies of the 11th and 12th vertebrae. It continues into the abdomen along the anterior border of the Psoas, and therefore passes behind the medial arcuate ligament—though it may pierce the crus of the diaphragm. The intercostal arteries and veins cross the trunk posteriorly; so does the large branch from Th. 1 to the lower trunk of the brachial plexus.

In front of each rib it has a ganglion. As *ganglia* are segmental structures, there is developmentally one for each of the 31 pairs of spinal nerves; but, owing to their tendency to amalgamate, there are with fair constancy only 3 cervical, 11 thoracic, 4 lumbar, 4 sacral pairs, and 1 coccygeal (unpaired). The inferior cervical and the first thoracic ganglia are usually (about 65 per cent) amalgamated and may be referred to collectively as the *stellate ganglion.* The origin of the vertebral artery from the subclavian artery lies close in front of this ganglion; so, it is not easily seen.

Connections. From the anterior rami of a limited number of spinal nerves (all the thoracic and the upper two or three lumbar) a white ramus communicans passes forwards and medially to

join the corresponding sympathetic ganglion; while the anterior ramus of every spinal nerve without exception receives from a sympathetic ganglion one or more gray rami communicantes. From the upper five thoracic ganglia, gray non-medullated fibers pass to the cardiac plexus (1st–5th), posterior pulmonary plexus (2nd, 3rd, and 4th), and upper part of the aorta and the oesophagus. Either the splanchnic nerves or the lower ganglia supply the lower thoracic portions of the aorta and oesophagus From the (5th), 6th, 7th, 8th, 9th, and 10th ganglia a large medullated nerve, the *great splanchnic nerve*, larger than the sympathetic trunk itself, runs downwards, just lateral to the azygos or hemiazygos vein, pierces the corresponding crus of the diaphragm, and ends in the celiac ganglion. From the 10th and 11th ganglia the *small splanchnic nerve* runs downwards and medially through the crus to end in the lower part of the celiac ganglion (aorticorenal ganglion), while a branch of the 12th ganglion, the *smallest splanchnic nerve*, takes a similar course to end in the renal plexus.

Note. (a) Whether a nerve be white or gray depends on whether or not its individual nerve fibers have or have not medullary sheaths. After taking part in a synapse a medullary sheath is usually lost. (b) The splanchnic nerves are in reality white rami communicantes that make "non-stop journeys" through sympathetic ganglia (*fig. 763*) and end in the celiac and renal ganglia whence they are relayed as non-medullated fibers. (c) The gray rami communicantes and the visceral branches to the aorta, oesophagus, heart, and lungs are non-medullated fibers that have been relayed in sympathetic ganglia. (d) Rami communicantes obviously approach the sympathetic ganglia from the postero-lateral direction; whereas visceral branches pass from the antero-medial border.

THE LUNGS (PULMONES)

The shape of the lungs, like that of the liver and spleen, depends largely upon the surrounding structures, and the impressions these make are best observed in formalin hardened specimens. A full description of the form and relations of the lungs is in large measure redundant, since it is a description of the counter part of the parietal pleura already given.

The lungs are conical (*fig. 550*). Each lung has an apex and base, costal and

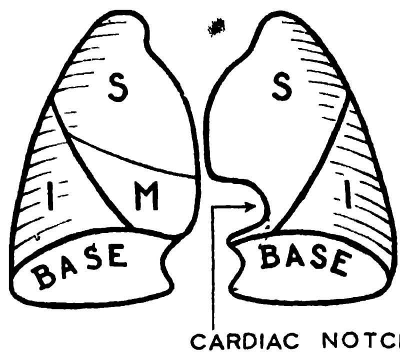


FIG. 550. The lungs, anterior aspect.

mediastinal surfaces, anterior, inferior and posterior borders, and a hilum.

The *apex* rises to the neck of the first rib.

The *base* or diphragmatic surface is concave. Because the right dome of the diaphragm rises higher and is more convex than the left dome, the right lung is shorter and its base is more deeply excavated than the left. The right base overlies the liver; the left base overlies the liver, stomach, and spleen.

The *costal surface* may bulge slightly into the obliquely set intercostal spaces.

The *mediastinal surface* (*fig. 552*) bears the impress of the structures covered

with the mediastinal pleura. The most noticeable feature of this surface is the hilum of the lung and the attachment of the pulmonary lig. which descends from the hilum (*fig. 551*). In front of these,

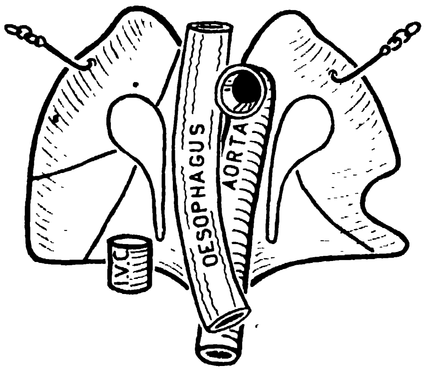


FIG. 551. The mediastinal surfaces of the lungs. This picture reveals the posterior, lateral and anterior relations of the pericardium.

pericardial excavation: (a) the groove for the s. v. cava descends in front of the lung root; (b) the much larger groove for the i. v. cava ascends in front of the pulmonary ligament. The phrenic nerve and its vessels create no perceptible groove. Arching over the lung root, and therefore in the superior mediastinum, is the arch of the azygos vein on the right side; the arch of the aorta on the left. The grooves produced by these two vessels can be followed downwards, behind the hilum and ligament of the respective lung, through the entire length of the posterior mediastinal surface. Only when the azygos vein is engorged is its groove well marked. The right margin of the oesophagus produces a groove between the hilum and ligament of the right lung in front and the groove for the

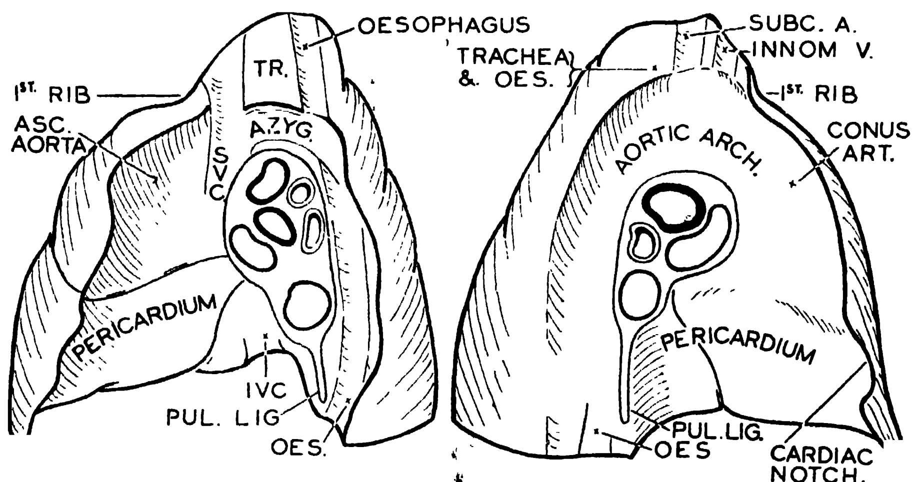


FIG. 552. Impressions commonly made on the mediastinal surfaces of the lungs. Of course, some intimate relations (e.g., phrenic n.) make no impressions.

the excavation caused by the pericardial contents (i.e., middle mediastinum) is deeper on the left side than on the right, because two-thirds of the heart lie on the left of the median plane. Two vertical grooves for the caval veins join the right azygos vein behind; the lower end of the left margin of the oesophagus makes an imprint on the left lung between the lower end of the left pulmonary ligament and the groove for the descending aorta (*fig. 552*).

Throughout the length of the right lung above the level of the arch of the azygos vein, there are 3 grooves (or areas) for– the oesophagus, trachea, and s. v. cava (and its upward continuation called the right innominate vein). Behind the latter is the innominate artery. The right vagus makes no mark.

Throughout the length of the left lung above the level of the aortic arch, there are areas or grooves for —the left subclavian and left common carotid arteries which largely conceal the trachea and oesophagus; and in front of the common carotid is the left innominate vein. The left vagus and the thoracic duct make no mark.

As stated already, the lungs fill the *pleural spaces* except at three sites, called the right and left costo-diaphragmatic and left costo-mediastinal recesses. The lower limits of the costo-diaphragmatic recesses are related to ribs 8, 10, and 12; the lower borders of the lungs are related to ribs 6, 8, and 10; so, they are two ribs higher. The *cardiac notch*, or "bite" that the heart takes out of the anterior border of the left lung, is greater than the bite it takes out of the left pleura—hence the left costo-mediastinal recess. During inspiration the lungs invade, but do not fill, the pleural recesses.

The *anterior borders* of the lungs are pinched between the body of the sternum and the pericardium; so, they are thin and sharp. On the left side the cardiac notch extends from the fourth to the sixth costal cartilage. The pericardium here comes into contact with the left side of the sternum and is separated from the fourth, fifth, and sixth costal cartilages by the two layers of parietal pleura that bound the costo-mediastinal recess and by the Transversus Thoracis.

This area on the left side of the thorax unoccupied by lung is called "the area of superficial cardiac dulness".

Above the level of the sternal angle the anterior borders of the right and left lungs diverge and are grooved successively by the first rib, subclavian vein, and subclavian artery (or more precisely by the innominate vein on each side, the innominate artery on the right, the subclavian artery on the left). The *inferior border* projects into the costo-diaphragmatic recess; so, it is sharp. The *posterior border* is massive and rounded.

Lobes and Fissures. In each lung a complete fissure, the *oblique fissure*, cuts through the costal, diaphragmatic, and mediastinal surfaces as far as the root. It crosses the posterior border $2\frac{1}{2}$ inches below the apex, and the inferior border about 2 inches from the median plane. When the arm is raised above the head, the vertebral border of the scapula practically overlies this oblique fissure. On the right side a second equally complete fissure, the *transverse fissure*, runs horizontally at the level of the 4th costal cartilage to meet the oblique fissure in the midlateral line. The right lung has, therefore, three lobes--upper, middle, and lower; the left, two—upper and lower.

The antero-inferior part of the left upper lobe is called the *lingula*. The lingula (lingular process) and the cardiac notch above it correspond to the middle lobe of the right lung. The middle lobe lies at the front of the chest, its tail-like apex reaching the midlateral line. You can cover it with your own hand placed on your chest.

VARIATIONS. The number of lobes may be decreased or increased. Thus, the middle lobe of the right lung is very commonly extensively fused with the upper lobe, and it is not uncommonly partially fused with the lower lobe; the

upper and lower lobes (of both lungs) are commonly fused above the hilum.

The right lung may have six lobes—the usual three and three others. Thus, (a)

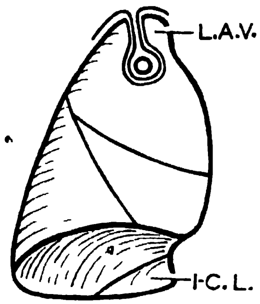


FIG. 553. Accessory lobes of the right lung Infracardiac lobe: Lobe of the azygos vein

apex. It results when the apex of a developing right lung encounters the arch of the azygos vein and is cleft by it, a portion of the apex coming to lie on each side of the vein (*fig. 553*). The vein is suspended in a pleural "mesentery", and it may cause a shaddow by X-ray. (c) The *infracardiac lobe* is constant in quadrupeds. In them it intervenes between pericardium and diaphragm. In man the pericardium fuses with the diaphragm and the lobe is generally suppressed. Further, the right *eparterial bronchus* (i.e., the first branch of the right bronchus) may arise from the trachea, as in the sheep and pig.

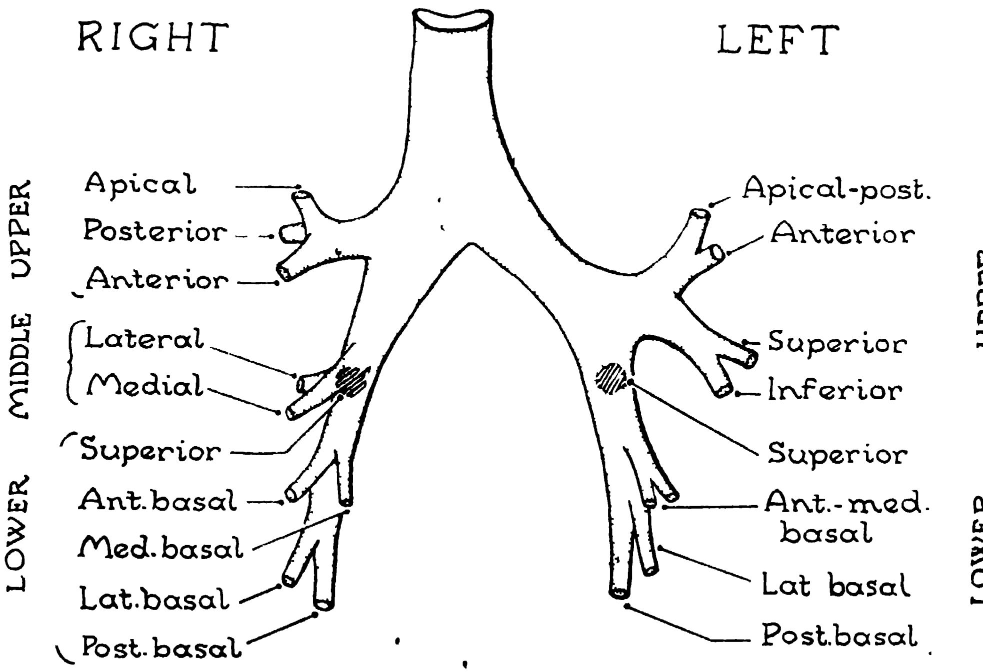


FIG 554. The 10 right and 8 left segmental bronchi. (After Jackson and Huber.)

the *superior segment of the lower lobe* (i.e., apical or dorsal segment) is commonly either partially or completely separated by a fissure from the lower lobe. (b) The *lobe of the azygos vein*, said to be constant in the porpoise, is really a bifid

The left lung may have (a) the *superior segment of the lower lobe* and (b) the *lingular segment* of the upper lobe partially or completely separated by fissures. Indeed, additional fissures have been described between most broncho-pul-

monary segments and between many subsegments (Foster-Carter).

The Bronchial Tree (*figs. 554, 556*). The trachea bifurcates on the plane between the superior and inferior mediastina (4–5 disc) into a right and a left *primary* (main) *bronchus* for the supply of the respective lungs. Each primary bronchus descends to the hilum of its own lung where it lies behind the pulmonary vessels and on a level with the 5th and 6th vertebral bodies. On the right side it gives off three *secondary* (lobar) *bronchi*, and on the left side, two, for the corresponding lobes of the lungs. The secondary or lobar bronchi divide into *tertiary* (segmental) *bronchi*. Each tertiary or segmental bronchus, together with the portion of the lobe it supplies, is called a *broncho-pulmonary segment* (*fig. 555*). There are usually 10 broncho-pulmonary segments on the right side, and 8 on the left side; and their mouths are visible through the bronchoscope. These are constant within certain limits, determined by minor variations in the branching of the bronchi.

As the bronchi continue to branch and rebranch, the broncho-pulmonary segments subdivide into smaller and smaller subsegments, until the ultimate, called a *lung unit*, or *primary lobule*, is reached p. 530).

Although it is customary to describe the right lung as having 3 lobes and the left as having 2, the bronchi are distributed nearly symmetrically on the two sides. Indeed, did the left apical-posterior and the left anterior-medial-basal bronchi arise earlier, the similarity would be almost complete.

In man, who has assumed an upright posture, the natural method of emptying the tracheo-bronchial tree of accumulated secretion and particulate matter is by ciliary action and by coughing. But, by assuming various recumbent postures, the assistance of gravity may be obtained. This was appreciated by H. P. Nelson who investigated the bronchi with this fact in mind and described the particular posture best suited to draining into the trachea the contents which,

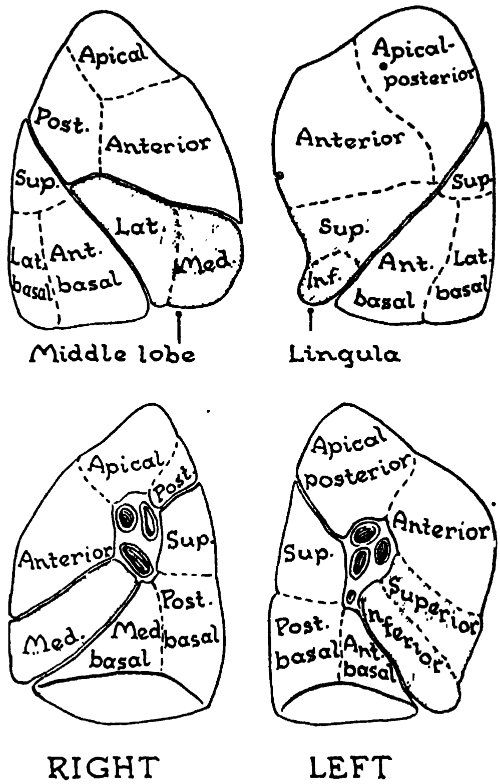


FIG. 555. The 10 right and 8 left broncho-pulmonary segments. (After Jackson and Huber.)

under pathological conditions, have accumulated in a given bronchus. Others have related the broncho-pulmonary segments to the surface of the lung and to the surface of the body, thereby indicating where they are accessible to surgical treatment (e.g., removal or drainage); the bronchoscopist's approach (e.g., removing an aspirated foreign body) is via the larynx and trachea.

TABLE 19

Names of the Broncho-pulmonary Segments

RIGHT LUNG		LEFT LUNG		
Lobes	Segments	Lobes		Segments
Upper	Apical Posterior Anterior	Upper	Upper Division	Apical-posterior Anterior
Middle	Lateral Medial		Lower (Lingular) Division	Superior Inferior
Lower	Superior Medial Basal Anterior Basal Lateral Basal Posterior Basal	Lower		Superior Anterior-medial Basal Lateral Basal Posterior Basal

Nomenclature. By the pioneers various names, each appropriate in its own way, have been applied to the various broncho-pulmonary segments. From the many conflicting synonyms employed, Jackson and Huber suggest the nomenclature that is adopted in this book because of its simplicity and ease Each segment is named according to its position in a lobe. The term anterior is preferred to pectoral, and lateral to axillary; all segments that contribute to the basal or diaphragmatic surface of the lower lobe are described as basal; hence, medial-basal is preferred to cardiac.

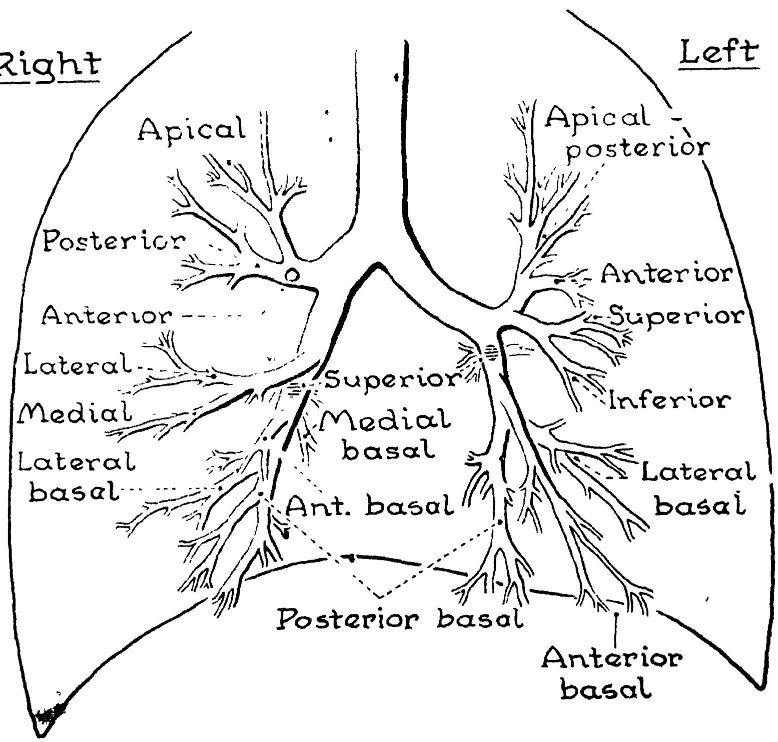


FIG. 556. The distribution of the front view. (After Nelson, modified.)

It can be observed that the right upper lobe bronchus (eparterial bronchus) arises 1 inch from the tracheal bifurcation. After the course of 1 cm. it divides into its three segmental bronchi. The right middle lobe bronchus arises about 2 cm. below the upper lobe bronchus. The left upper lobe bronchus, corresponding to the right upper and middle lobe bronchi, arises 2 inches from the tracheal bifurcation. After the course of less than 1 cm. it divides into its two segmental bronchi. Owing to its low origin the apical-posterior bronchus and its branches make a steep ascent. The superior (dorsal) lower lobe bronchi of both sides arise almost opposite the mouths of the right middle and left upper lobe bronchi respectively. The posterior basal bronchus is the largest of the lower lobe segmental bronchi; it may be regarded as the continuation of the stem of the bronchial tree.

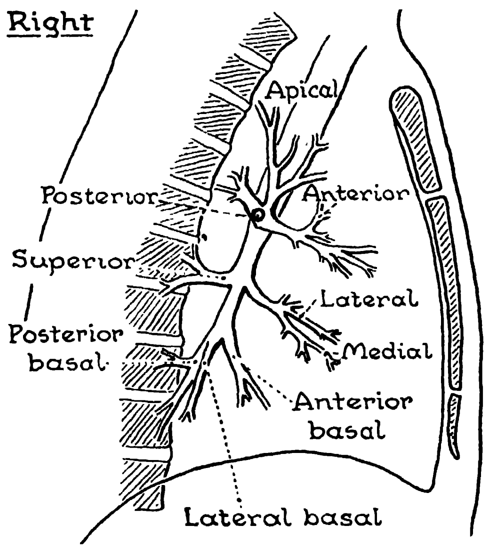


FIG. 557. The distribution of the right bronchus, side view.

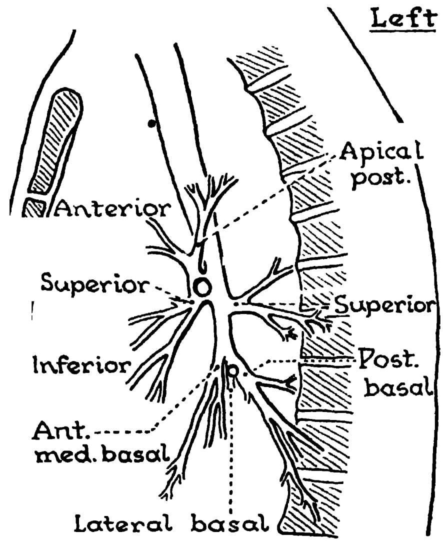


FIG. 558. The distribution of the left bronchus, side view. (After Nelson, modified.)

Structure. The C-shaped bars of hyaline cartilage found in the trachea and extrapulmonary bronchi give place in the intrapulmonary bronchi to plates of cartilage which are scattered irregularly around a circular lumen. The *bronchi* branch and rebranch until, as *bronchioli* 1 mm. or less in diameter, the cartilage and mucous glands cease; cilia are found as far as the respiratory bronchioli. The non-cartilaginous bronchioli now divide repeatedly, the smallest tubes being termed *terminal bronchioli*. Up to this point the branches of the bronchial tree are lined with a continuous layer of epithelium and, hence, are part of the purely conducting portion of the lung. Each terminal bronchiole gives rise to one or more *respiratory bronchioli*, which have alveolar outpouchings in their walls and, so, are the beginning of the respiratory part of the lung. The respiratory bronchiole ends in a number of *alveolar ducts*. From the latter arise the *alveolar sacs* and *alveoli* (air cells) (*fig. 559*). Just as the paranasal air cells are variable in shape and size, so are the terminal parts

of the respiratory system. In both instances one condition must be fulfilled—there shall be no unoccupied space. The finer ramifications of the bronchial tree remain fairly constant at about 0.3 mm. in diameter. Whether or not there are pores or perforations between contiguous alveolar sacs in man is disputed; in other mammals they seem to be present.

Wisps, of involuntary muscle fibers are wrapped around the bronchioles as

With or without a lens, finer lines are seen to subdivide these into *primary lobules* or *lung units*, each served by a respiratory bronchiole. The units show to good advantage when the bronchial tree has been filled with a white or a pale yellow injection mass.

Blood Vessels of the Lungs. *The Pulmonary Artery* of each lung (*fig. 561*) crosses over the main bronchus at the hilum and divides into 10 branches which

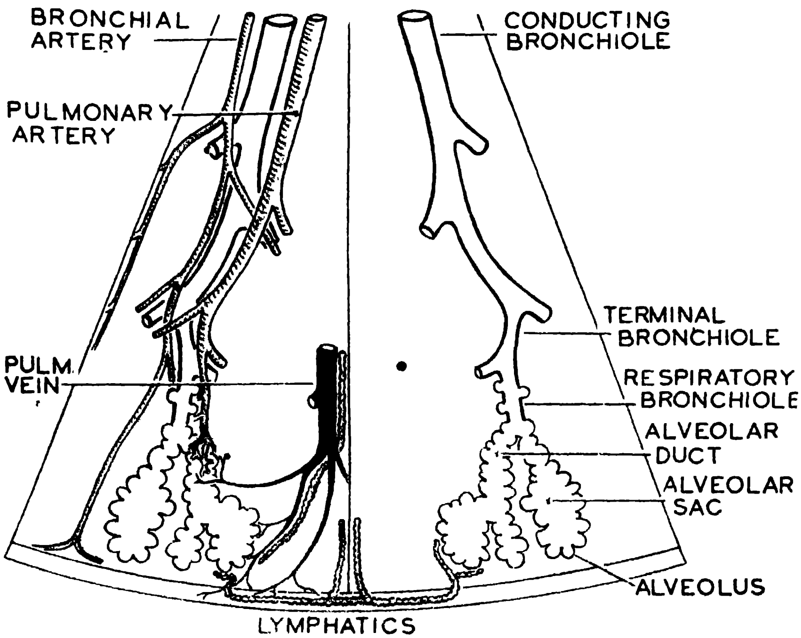


FIG. 559 Structure of a lobule of the lung

far as the ends of the alveolar ducts where they form sphincters for the alveolar sacs.

Lung Units. On the surface of the lung dark lines are seen to enclose *polygonal fields*, 10–20 mm. in diameter. They are the bases of piriform portions of lung, supplied by bronchioli 1 mm. or less in diameter, and enclosed by fibrous septa rendered black by inhaled pigment contained in lymphatics. These are anatomical or *secondary lobules* (*fig. 560*).

usually follow and cling to the posterolateral or superior aspect of the segmental bronchi. They are named after the 10 right segmental bronchi.

The Pulmonary Vein likewise has 10 branches. Their main stems usually follow the medial or inferior aspect of the bronchi. Peripherally, however, the veins lie intersegmentally and drain adjacent segments—and arteries from adjacent segments may cross the intersegmental planes. Hence, a bron-

cho-pulmonary segment should not be considered to be a morphologic broncho-vascular unit. (Boyden.)

On each side two pulmonary veins, an upper and a lower, enter the left atrium of the heart; on the left side they come from the respective upper and lower lobes of the lung; on the right side the upper vein drains the upper and middle lobes.

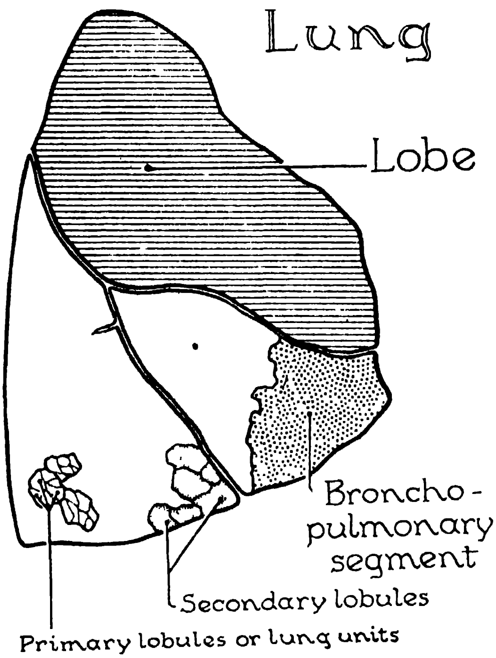


FIG. 560. The subdivisions of the lung.

The Bronchial Arteries are to the lungs what the hepatic artery is to the liver. Derived on the left side from the aorta; on the right either from an intercostal artery or from the left bronchial artery, each bronchial artery follows the posterior wall of the bronchus. It supplies the bronchi, the walls of the pulmonary vessels, and the lymph glands, and, after passing with radicles of the pulmonary vein through interlobular septa, it supplies the pleura. The blood delivered by the bronchial arteries is returned by radicles of the pulmonary veins, except that to the first two or three divisions of the bronchi which is returned by the bronchial veins to the azygos system of veins.

In the rabbit it is the pulmonary artery—not the bronchial—that supplies the lymphoid tissue and sends branches to the pleura.

There is no anastomosis between the bronchial and pulmonary arteries, except in the capillaries of the respiratory bron-

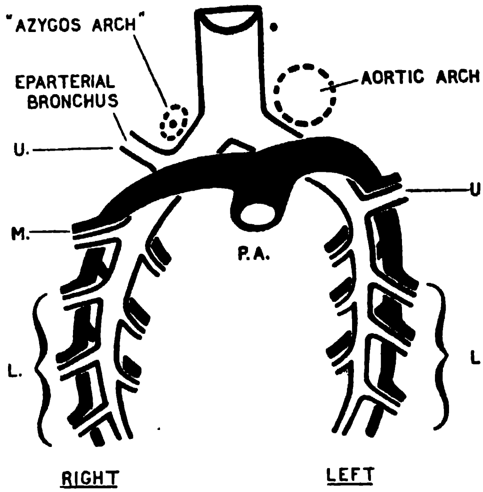


FIG. 561. Scheme showing general relationship of pulmonary arteries to bronchi, anterior view. U, M, and L = branches to upper, middle and lower lobes of the lungs.

chioles. This you might expect, for the bronchial arteries deliver arterial blood under high pressure; whereas the pulmonary artery delivers venous blood under low pressure. However, as a rare anomaly the bronchial artery replaces the pulmonary artery.

Lymph Vessels. The lymphatics of the lung are divided into two sets. One set drains the pleura, while the other accompanies the bronchi, the pulmonary artery, and the pulmonary vein. Both divisions end in the lymph nodes at the

hilum of the lung, but there is little communication between them, except in the pleura.

Nerves. The *vagus* and *sympathetic* (Th. 3, 4, 5) via the pulmonary plexuses supply the lungs. Afferent vagal fibers pass from the alveoli to the respiratory center to take part in the respiratory reflex. Efferent vagal fibers cause con-

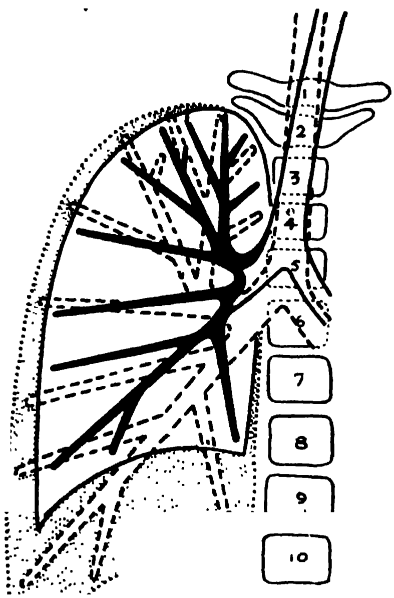


FIG. 562. Excursion of bronchial tree in forced inhalation (dotted lines) and forced exhalation (solid black) from X-ray pictures. (After C. C. Macklin.)

traction of the bronchial musculature; the sympathetic fibers cause relaxation; hence, spasms of the bronchi, as in asthma, are relieved by adrenalin. Each *phrenic nerve* is, of course, the sole motor nerve to the corresponding half of the diaphragm; but it is also the sensory nerve to the mediastinal pleura and to the central part of the diaphragmatic pleura. The *intercostal nerves* are sensory to the costal pleura and to a broad marginal strip of diaphragmatic pleura (*fig. 303*).

The visceral pleura, like the visceral pericardium and visceral peritoneum, is insensitive to mechanical stimulation.

Movements. The alterations in form of the bronchial tree are shown diagrammatically in figure 562. Observe that during inspiration (a) the bronchi become longer and wider but undergo little, if any, angle change; and (b) the root of the lung moves downwards and forwards. This root movement is of particular importance to the apex of the lung and to the part lying postero-superior to the root which cannot expand either upwards or backwards seeing the upper and posterior parts of the bony thorax are practically fixed. They can, however, expand in the opposite direction (downwards and forwards) thanks to the fact that the lung root moves in this direction. If for any reason the root is fixed the apical region can hardly expand.

Elastic fibres form a longitudinal network within the tunica propria throughout the entire tracheobronchial tree and this network is probably by far the most efficient part of the recoil mechanism of the entire lung. (Macklin.)

The crying of a child at birth causes the lungs to expand, but not for a fortnight are they fully expanded, the order being antero-lateral, diaphragmatic, apical, and posterior areas (Todd).

Surface Anatomy in the Living. The data given in the text on the positions and levels of viscera and other structures with reference to the vertebrae, costae, and sternum are from observations that may be made on the cadaver. Under dissecting room conditions the cadaver is supine, the elastic lungs have collapsed, the thorax is in the extreme phase of expiration, and the diaphragm, being relaxed,

is forced cranially and dorsally by the abdominal viscera. Now, X-ray examinations of the living adult subject, particularly when in the erect posture, modify the cadaveric picture and show a general lowering of the viscera due to gravitational pull. Thus:

The Tracheal Bifurcation, both in the cadaver and in the supine living subject, lies at T. 4—5; but when erect it is commonly at T. 6 or even lower. Moreover, it descends during inspiration (*fig. 615*). During the first year of life it lies at T.3 or 4; from the 2nd to 6th year at T. 4 or 5; and from the 7th to 12th year at T. 5 or 6. *The Domes of the Diaphragm* fall nearly 1″ when the erect posture is assumed; similarly the *Aortic Arch* may sink into the inferior mediastinum; and the *Heart* likewise descends (p. 537). *The Oblique Fissure of the Lung*, during life, is much lower than in the cadaver. Its posterior (upper) end lies deep to the 5th rib or 5th interspace; it follows the line of the 6th rib to its costo-chondral junction, which is 2″ from the sternal margin. On the left side it is a little higher and more vertical than on the right. (Brock.) *The Inferior Border of the Lung* which on p. 525, crosses ribs 6, 8, and 10, lies at a lower level, reaching its lowest when the patient is prone. *The Costal Reflexion of the Pleura* is quite variable posteriorly. Instead of crossing the 12th rib near its neck, it may cross as low as its tip, i.e., it descends to the level of vertebra L. 2 (Lachman.)

CHAPTER 18

THE PERICARDIUM AND ITS CONTENTS

The Pericardium (Gk. Peri = around; Kardia = the heart) consists of an outer *fibrous sac* which is lined with an inner *serous sac* into which the heart and the roots of the great vessels are invaginated. Hence, the serous pericardium has both a visceral and a parietal layer; whereas the fibrous pericardium has a parietal layer only.

When the pericardium is incised and the pericardial cavity thereby opened, the heart with an intimate covering of serous pericardium is seen to project into the pericardial cavity in precisely the same manner as the lung covered with pleura, and the liver covered with peritoneum project into the pleural and peritoneal cavities respectively, and as the testis covered with tunica vaginalis projects into the cavity of the tunica vaginalis testis. This is not surprising, for these four serous-lined, potential cavities were once continuous with each other, and together made up the embryonic celom.

The Fibrous Pericardium might be called the envelope of the middle mediastinum. Within it are not only the heart but also the roots of the eight great vessels that proceed to or from the four chambers of the heart. In man, who walks erect, the fibrous pericardium blends with the central tendon of the diaphragm, but in quadrupeds it is separated from the diaphragm by the infracardiac lobe of the right lung, a lobe that is rudimentary in man (*p. 526*). The ascending aorta carries the pericardium upwards beyond the heart to the level of the sternal angle, where it has a rounded summit. Its vertical diameter in the median sagittal plane is coextensive, therefore, with the body of the sternum; that is, it extends from the level of the sterno-manubrial joint above to the xiphisternal joint below. Its left border curves downwards and laterally to the apex of the heart, passing just medial to the lig. arteriosum and, therefore, to the recurrent laryngeal nerve, which are outside the sac. The right border curves downwards, crossing the s. v. cava obliquely below the entrance of the azygos vein; so, part of the s. v. cava is without and part within the fibrous pericardium (*fig. 563*).

The Serous Pericardium (*see p. 538*).

Obtain *5 wicker sticks* 6–8 inches long. Pass (1) vertically upwards through the i. v. cava, right atrium, s. v. cava, right innominate vein and perhaps into the right internal jugular vein (*fig. 563*), (2) horizontally through the left pulmonary artery, and right pulmonary artery (3) horizontally through the left upper pulmonary vein, left atrium, and right upper pulmonary vein, and (4) horizontally through the left lower pulmonary vein, left atrium, and right lower pulmonary vein, and (5) up the oesophagus. If left in position and palpated from time to time, these sticks will assist greatly in obtaining a clear idea of the orientation and relationships of parts.

The Heart. This muscular pump is somewhat larger than a closed fist. It has four chambers, the ***right*** and ***left atria*** and the ***right*** and ***left ventricles.*** The atria are separated from the ventricles by a constriction that completely en-

circles the heart and is appropriately called the *atrio-ventricular* (*coronary*) *sulcus*. The ventricles are separated from each other by the *anterior* and *inferior interventricular* (*longitudinal*) *sulci*. The notched antero-superior part of each atrium resembles a dog's ear and is called the *auricle*.

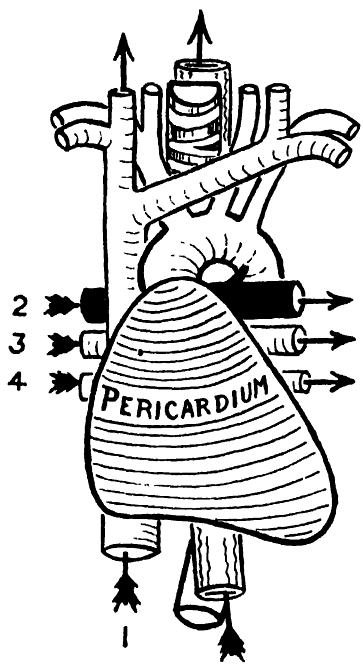


FIG. 563. The fibrous pericardium and the channels through which 5 wicker sticks have been passed.

The heart has 3 surfaces: *sterno-costal* (anterior), *diaphragmatic* (inferior), and *posterior* (anatomical base); it also has an *apex* (i.e., the lowest and leftmost point).

The Sterno-costal Surface of the Heart and Great Vessels. To be able to plot out this surface on the chest of the living is of such obvious importance that we shall make it the *key to the region*. You should practice drawing it on paper; and, in order that the finished sketch shall be more or less to scale, first draw the *sternum*: The body, consisting of 4 sternebrae, is to be more than twice the length of the manubrium. Project horizontal lines at the levels of the upper and lower borders of the manubrium, and draw a suitably curved line to represent the diaphragm, at the level of the xiphi-sternal joint. The region above the upper line is the neck; between the upper and intermediate lines, the superior mediastinum; between the intermediate and lower lines, the middle mediastinum; below the lower line, the abdomen. Insert the clavicles and the first, third, and sixth cartilages (*fig. 564 A*).

1. A vertical line drawn from the neck to the abdomen represents from above downwards the *right borders* of:

a. The right jugular vein.
b. The right innominate vein.
c. The superior vena cava (s. v. c.).
d. The right atrium.
e. The inferior vena cava (i. v. c.).

This line is situated less than a finger's breadth from the right margin of the sternum (*fig. 564 B*).

2. On each side the *jugular* and *subclavian veins* unite behind the sternal end of the clavicle to form the corresponding innominate vein.

3. The *left innominate vein* passes obliquely behind the upper half of the manubrium and joins the right innominate vein to form the superior vena cava. The site of junction obviously is behind the middle of the right margin of the manubrium (*fig. 564 C*).

4. The *superior vena cava* ends in the right atrium at the 3rd costal cartilage.

5. The inferior vena cava pierces the diaphragm at the level of the xiphisternal joint, and after a course of half an inch enters the right atrium, at the level of the 6th costal cartilage.

6. A slight bulge or convexity should

be added to the portion of the vertical line between the 3rd and 6th cartilages. It represents the right atrium, and is also the *right border* of the heart.

7. An appropriately crenated, oblique line will define the *left margin of the right atrium* and at the same time the right part of the atrio-ventricular sulcus.

8 The *inferior margin* of the heart lies on the convex diaphragm and, therefore, is slightly concave. It extends from the i. v. cava, a finger's breadth to the right of the sternum, across the xiphi-sternal joint to the apex of the heart, which is situated in the fifth left intercostal space or behind the sixth rib, 3½ inches from the median plane. One-third of the heart, therefore, lies to the right of the midline; two-thirds to the left.

9. The *left margin* is rounded, and passes from the apex to the second left interspace a finger's breadth from the sternal border.

10. The tip of the *left auricle* peeps round this margin in the second interspace.

11. A line parallel to the left margin, and about ⅓ of the distance from it to the right margin, separates the right and left ventricles and represents the *anterior interventricular sulcus*. Portions of all four chambers are now outlined on this sterno-costal surface. The portion of left ventricle appearing on this surface can almost be covered by a finger.

12. The *ascending aorta* is the segment of the aorta lying within the pericardium, and therefore in the middle mediastinum, and therefore below the level of the sternal angle, and therefore behind the 1st sternebra. As the continuation of the left ventricle, it passes upwards and to the right and overlaps the s. v. cava. Where it crosses the sterno-manubrial joint, it leaves the pericardium and becomes the *aortic arch*. The arch passes backwards and to the left behind the lower half of the manubrium, and therefore below the level of the left innominate vein, to reach the lower border of the 4th thoracic vertebra on its left side. There, crossing the plane between the superior and inferior mediastina, it becomes the *descending thoracic aorta* (*fig. 565 A*).

13. The *pulmonary artery*, as the con-

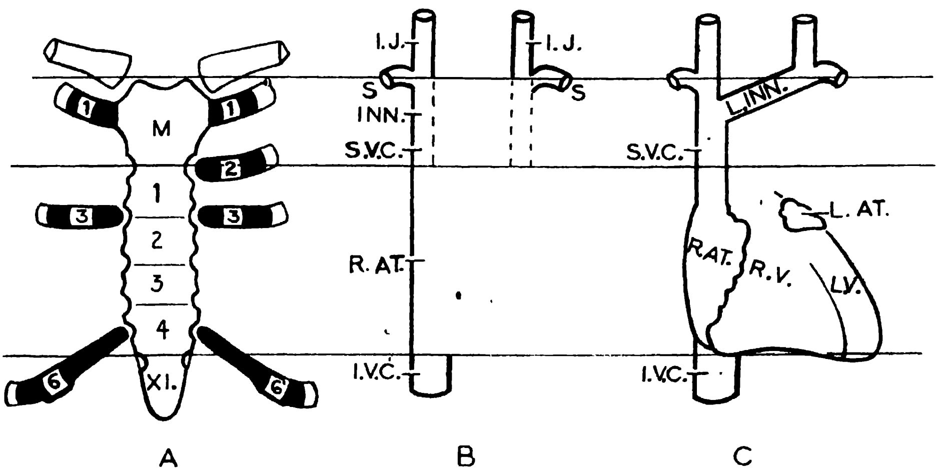


FIG. 564. The sterno-costal surface of the heart and the great veins constructed on projection lines.

tinuation of the right ventricle, passes upwards and to the left between the right and left auricles, which embrace it. It lies in front of and conceals the root of the aorta. Below the aortic arch it divides like the letter T into *right* and *left pulmonary arteries;* they pass to the roots of the lungs (*fig. 565 B*). Our study of the mediastinal pleura has taught us that the descending aorta passes behind the root of the left lung and that the s. v. cava passes in front of the upper part of the root of the right lung; so, the courses of the right and left pulmonary arteries are evident—the *left* passes anterior to the descending aorta; the *right* posterior to the ascending aorta and s. v. cava (*fig. 563*). Observe that the stick passed through the right and left pulmonary arteries inclines down wards from the left 2nd to the right 3rd cartilage; for later it will be seen that these arteries define the upper limit of the heart.

14. The *ligamentum arteriosum* (ductus arteriosus), being the posterior segment of the left primitive sixth aortic arch, passes from the *left* pulmonary artery to "the aortic arch" which it joins outside the pericardium, beyond the origin of the subclavian artery.

Surface Anatomy of the Heart. Figure 566A depicts the surface anatomy of the heart of an average adult cadaver lying on its back. During life, however, and standing erect X-rays give the lower position seen in figure 566B. The inferior border of the heart crosses the median plane 5.5 cm. below the xiphi-sternal joint. From this it would appear that the diaphragm passes from the xiphoid first dorsally and caudalwards—not dorsally and cranialwards. While recumbent, the cadaveric position is almost achieved, except for the inferior border which is now 3.5 cm. below the xiphi-sternal joint. (Mainland and Gordon.)

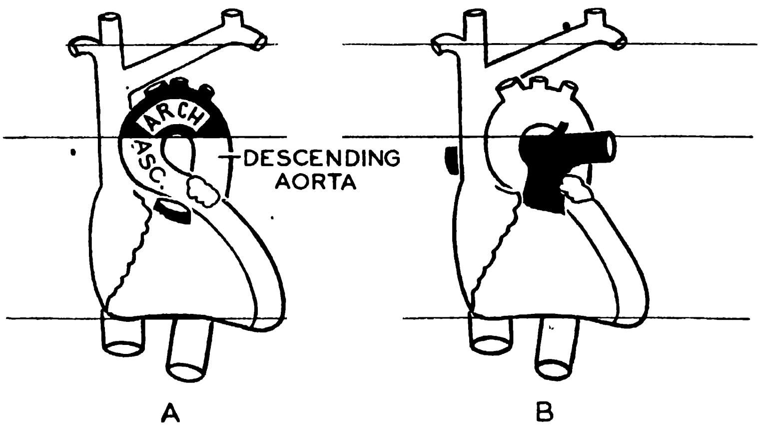


FIG. 565. (A) The aorta. (B) The pulmonary artery.

The pericardium is attached to the diaphragm; so, the heart must move with the diaphragm. Accordingly, deep inspiration and expiration have most effect on the position and shape of the heart (*fig. 567*). On inspiration it is a "vertical heart"; on expiration it is a "transverse heart." Now, (a) a broad stocky build, (b) the recumbent position, and (c) a distended abdomen (e. g., pregnancy, gas, fat, and the large liver of childhood) are asso-

ciated with a high diaphragm and, therefore, with transverse hearts; whereas those who are tall and slender have vertical hearts. (Lachman.)

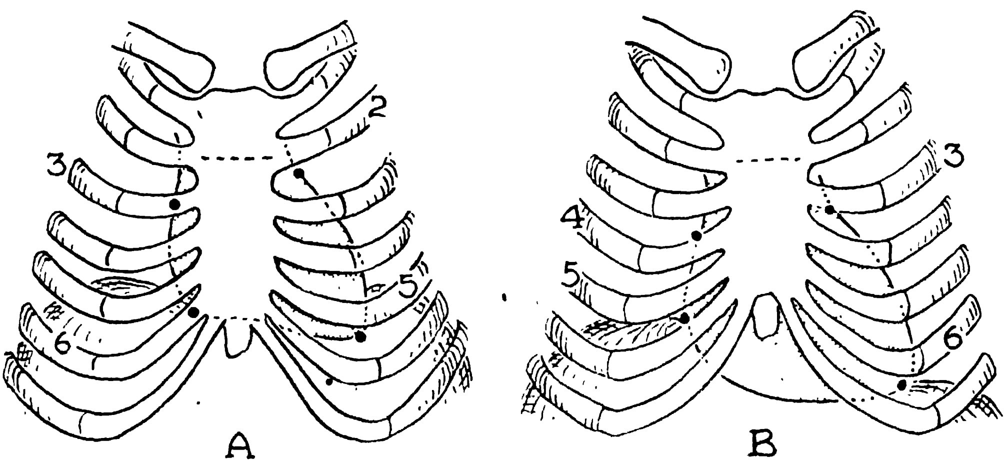
Serous Pericardium. Before examining the inferior and posterior surfaces of the heart observe these three points about the serous pericardium:

1. THE S. V. CAVA AND I. V. CAVA are clothed in serous pericardium in the same fashion as the ascending and descending colons are clothed in peritoneum; that is, they are covered in front and at the sides, but they are bare posteriorly.

2. THE OBLIQUE PERICARDIAL SINUS. Let two fingers be passed upwards behind the heart, on the left of the i. v. cava. They enter a recess comparable in shape, in size, and in that it lies on the left of the i. v. cava, to the upper recess of the lesser sac of peritoneum that lies behind the caudate lobe of the liver. The sinus is limited *at the sides* by the two right and two left pulmonary veins (which having pierced the fibrous pericardium, soon enter the left atrium) as well as by the i. v. cava on the right. *In front* is the left atrium. The fingers, in fact, palpate the two horizontal sticks that pass through the pulmonary veins and left atrium, and reach upwards almost to the level of the stick that passes through the right and left pulmonary arteries (*fig. 568*).

Cut across the i. v. c. as low as possible within the pericardium, raise the heart, cut vertically through the parietal pericardium *behind* the oblique sinus, and display the descending aorta and the oesophagus situated between the two lungs. Observe that the thickness of the pericardium and oesophagus is all that intervenes between the left atrium and the food you swallow (*figs. 547, 551*).

3. THE TRANSVERSE PERICARDIAL SINUS. Let the index and thumb meet behind the stems of the aorta and pulmonary artery. They do so in the transverse pericardial sinus. It is instructive to pass a wicker stick (or a finger) through this sinus. It should be insinuated from the right side, between the s. v. cava and the ascending aorta, and encouraged to the left until it



In the supine cadaver — In the erect living subject.

FIG. 566. The surface anatomy of the heart. (From Lachman, after Mainland and Gordon.)

emerges between the left auricle and the pulmonary artery. The stems of the aorta and pulmonary artery may now be cut across and displaced, when the stick will be seen to lie in front of the s. v. cava and the upper portions of the right and left atria. It will be understood (1) that the stick could not have passed between the aorta and the pulmonary artery because these two vessels, having been formed by the splitting of a single vessel, the *truncus arteriosus,* are still along it. Its course is slightly oblique. The right and left pulmonary arteries, lying immediately above and parallel to the upper border of the atria and upper pulmonary veins, are exposed by stripping up the pericardium (*fig. 599*).

The Inferior or Diaphragmatic Surface of the Heart, formed by the ventricles, is separated from the liver and stomach by the diaphragm. The inferior interventricular sulcus divides this surface into a right $\frac{1}{3}$ and a left $\frac{2}{3}$.

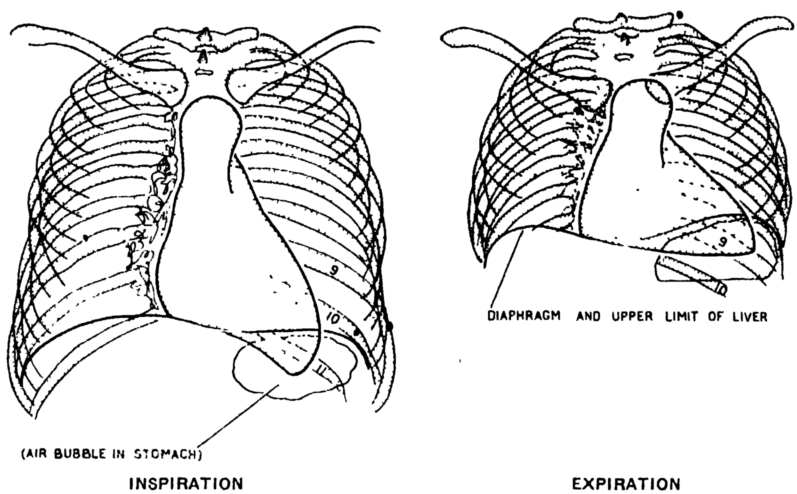


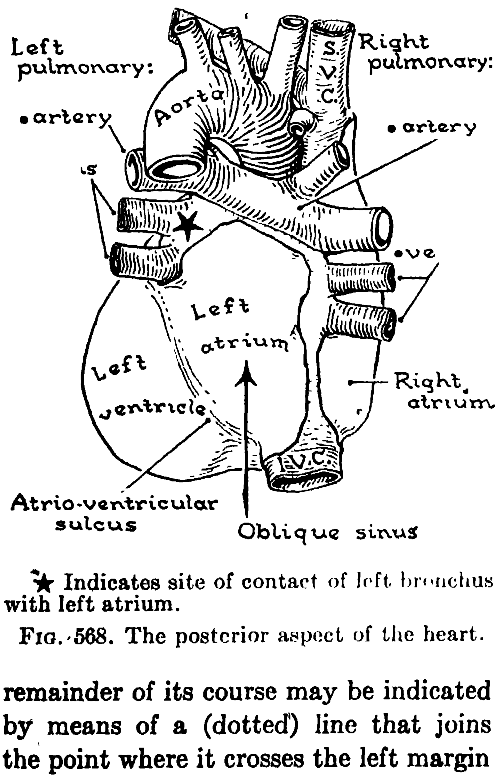
FIG. 567. Tracings of radiograms of the heart and diaphragm of a healthy adult male, showing their ever changing shapes and positions.

enveloped in their original single sleeve of pericardium; and (2) that the s. v. cava opens into the right atrium as a river opens into a lake, i.e., without sharp demarcation, a line cannot be drawn where the one ends and the other begins; hence, the ascending aorta, which is anterior to the atria, is also anterior to the s. v. cava.

The Upper Border of the Atria, which is also the upper border of the heart, should be exposed. This is done by **rendering prominent the stick traversing the right and left upper pulmonary veins, and then incising the visceral pericardium**

The Posterior Surface of the heart is formed by the atria. It is quadrangular. Like the inferior surface, it is divided into a right $\frac{1}{3}$ and a left $\frac{2}{3}$, the dividing line running vertically between the i. v. cava and the two right pulmonary veins. The right and left pulmonary arteries run along its upper border; the coronary sinus, lying in the coronary sulcus, runs along its lower border. The oblique pericardial sinus lies behind the left atrium. The pericardium separates this surface from the descending aorta, the oesophagus, and on each side of these, the right and left lungs (*fig. 551*).

Sulci. The *atrio-ventricular* (coronary) *sulcus* should be traced round the heart, which it completely encircles between the atria and the ventricles. Follow it from in front of the i. v. cava, round the inferior margin, upwards across the sterno-costal surface between the right atrium and the right ventricle, through the transverse pericardial sinus, and between the left auricle and left ventricle, to the left margin of the heart. The



★ Indicates site of contact of left bronchus with left atrium.

FIG. 568. The posterior aspect of the heart.

remainder of its course may be indicated by means of a (dotted) line that joins the point where it crosses the left margin to where it crosses the inferior margin (*fig. 570*). This is seen when the apex is raised up.

The *anterior interventricular sulcus* extends from the coronary sulcus at the left of the root of the pulmonary artery, downwards across the sterno-costal surface, round the inferior border $\frac{3}{4}''$ to the right of the apex. There it becomes continuous with the *inferior interventricular sulcus*, which continues backwards on the diaphragmatic surface to meet the coronary sulcus again at the left of the i. v. cava. The main cardiac vessels and the coronary sinus, often embedded in fat, occupy the sulci.

The Ascending Aorta and the Pulmonary Artery lie within the fibrous pericardium behind the 1st sternebra, the pulmonary artery extending beyond its left margin to the 2nd intercostal space. Having a common derivation from the truncus arteriosus, they lie within a common sleeve of serous pericardium; so, the transverse pericardial sinus is behind them both. The upper parts of the atria, their auricles, and the entering s. v. cava embrace the two great arteries from behind but fail to meet in front of them. Here the pleurae and lungs cover them.

THE PULMONARY ARTERY begins in front of the aorta and passes round it, going spirally upwards, backwards, and to the left until it reaches the concavity of the aortic arch where it bifurcates into the right and the left pulmonary artery. The stems of the right and left coronary arteries pass forwards, one on each side of the root of the pulmonary artery (*fig. 570*). The *right* and *left pulmonary arteries* (a stick has been passed through them) lie along the upper borders of the atria and of the upper pulmonary veins like the cross stroke of the letter T, set slightly obliquely—the right limb is longer and lower than the left limb. Behind the right and left arteries lie the bronchi and the inferior tracheo-bronchial glands; the glands exclude the oesophagus from contact (*fig. 599*).

THE ASCENDING AORTA begins behind the pulmonary artery and passes obliquely upwards, forwards, and to the right to reach the right margin of the

sternum. Its posterior relations are the upper parts of the atria and the left margin of the s. v. cava, the right pulmonary artery (and slightly the right bronchus).

The Aortic and Pulmonary Valves. (The ascending aorta and the pulmonary artery were cut across, after a stick had been passed through the transverse pericardial sinus.) The circumference of the ascending aorta is seen to be, not circular but elliptical; for, where the current of blood expelled from the left ventricle beats against its right wall, it is enlarged

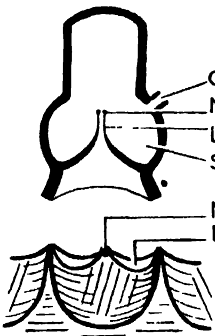


FIG. 569. The **aortic valve: on sagittal section, opened up.**

to form the *bulb of the aorta*. The aortic valve lies ¼″ lower than the pulmonary valve; is postero-medial to it; and faces a different direction (*fig. 570*). The aortic *valve* faces upwards, forwards, and to the right; the pulmonary valve upwards, backwards, and to the left. Both valves prevent back flow of blood into the ventricles, and both have three semilunar cusps, the aortic cusps naturally being stronger than the pulmonary cusps.

Each *cusp* has a fibrous basis covered on both surfaces with endothelium. At the middle of the free edge of each cusp there is a *fibrous nodule*, and on each side of the nodule there is a thin, crescentic area, the *lunule* (*fig. 569*). When the valve closes, the nodules meet in the center of the lumen and the ventricular surfaces of the lunules of contiguous cusps are applied to each other. Perhaps the nodules prevent slipping.

At the root of both arteries there are three dilatations, the *sinuses* (of Valsalva); one is placed external to each cusp. But for these sinuses, the cusps would stick to the wall of the artery when the valve is open. The pressure of blood in the sinuses after ventricular systole closes the valve.

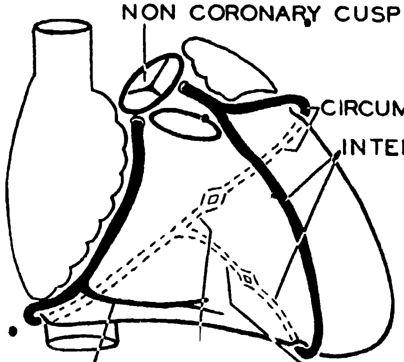


FIG. 570. **The coronary arteries placed on figure 565.**

The aortic orifice and the first quarter of an inch of the aorta are fibrous and not dilatable; so, the valve remains competent. The disposition of the cusps is explained on page 546 (*figs. 578, 587*).

The Blood Supply of the Heart may be studied under 3 headings:

(1) The coronary arteries and cardiac veins
(2) The myocardial circulation,
(3) The collateral circulation—
  (a) intrapericardial,
  (b) extrapericardial.

The Right and Left Coronary Arteries supply the heart. They spring from the (primitive) right and left aortic sinuses (*fig. 578*) just below the level of the free

edges of the cusps. The three sinuses and cusps of the aortic valve are referred to as the right and left coronary sinuses and cusps and the non-coronary sinus and cusp. The two coronary arteries pass forwards, one on each side of the root of the pulmonary artery, sheltered by the corresponding auricle. The main branches occupy the atrio-ventricular and interventricular sulci (*fig. 570*). So, if you can picture the sterno-costal surface of the heart, the courses of the arteries will present no difficulty.

The Left Coronary Artery divides into: (a) an *interventricular branch* which descends in the anterior interventricular sulcus to the sharp inferior margin of the heart, where it turns round into the inferior interventricular sulcus, and (b) a *circumflex branch* which runs in the atrio-ventricular (coronary) sulcus round the left margin of the heart.

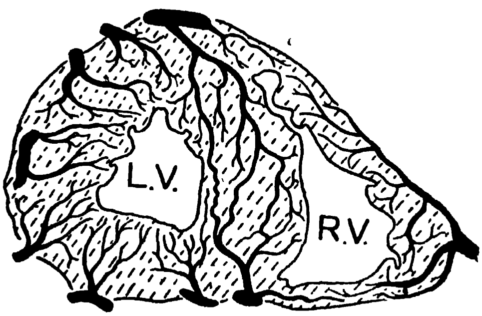


FIG. 571. Transverse section of ventricles showing branches of coronary arteries plunging into the heart substance. (After Gross and Kugel.)

The Right Coronary Artery descends in the right part of the atrio-ventricular sulcus, turns round the inferior margin of the heart in it, and divides into: (a) an *interventricular branch* which anastomoses in the inferior interventricular sulcus with the interventricular branch of the left left coronary, and (b) a *transverse branch,* which anastomoses in the atrio-ventricular sulcus with the circumflex branch of the left coronary artery. It sends (c) a large *marginal branch* along the inferior margin of the right ventricle.

Branches plunge at right angles from the surface vessels through the heart substance and anastomose richly (*fig. 571*).

Anomalies. There may be only *one coronary artery,* the result of suppression of the main stem of one or other artery. In this case the normal anastomosis between the branches of the two arteries in the atrio-ventricular sulcus is enlarged.

Accessory coronary arteries spring from the aortic sinuses in about 4 per cent of hearts. They are the result of early division of a main coronary stem.

The Cardiac Veins mostly accompany the arteries in the sulci and tend to lie superficial to them; so, they are very easily depicted (*fig. 572*). Five of the six cardiac (coronary) veins mentioned below end in the coronary sinus.

The Coronary Sinus is derived from the left limb of the sinus venarum; it lies in the atrio-ventricular sulcus at the lower end of the oblique pericardial sinus; it is about an inch and a half long; it is covered with cardiac muscle; and it opens into the right atrium at the left of the orifice of the i. v. cava, where a valve, so-called, guards it. At its left end it receives the companion of the left coronary artery, called the *great cardiac vein.* This vein follows first the course of the interventricular branch of the left coronary artery and then the circumflex branch. The companion of the marginal artery, called the *small cardiac vein,* enters the right end of the coronary sinus. The companion of the inferior interventricular branch of the right coronary artery, called the *middle cardiac vein,* ends in the coronary sinus, so do *inferior ventricular veins* from the diaphragmatic surface of the ventricles. The *oblique vein* is a twig that lies behind

the left atrium and ends in the coronary sinus. Developmentally, the oblique vein is the terminal part of the left common cardinal vein, and therefore the terminal part of the left superior vena cava, when such is present. It is, therefore, not surprising to find it continued across the front of the left pulmonary veins and artery as a thread lying within a pericardial fold (the vestigial fold of Marshall).

One or two large *anterior cardiac veins* pass from the front of the right ventricle, across the atrio-ventricular sulcus, and open directly into the right atrium.

The mouths of the great and small cardiac veins commonly have single cusped valves, but these are rarely competent. Minute veins, *Thebesian veins*, begin in the heart wall and open directly into the chambers of the heart.

The Myocardial Circulation. The heart muscle is provided with a vasculature more complex than that in most parts of the body where arterioles open into a capillary bed which in turn is drained by venules. Like the kidney, liver, and spleen, the heart has an arrangement peculiar to itself. This can best—indeed can only—be understood by reference to the facts of comparative anatomy and of embryology. Thus, the primitive vertebrate heart (the lamprey) is a non-vascular heart—there are no coronary vessels, and the myocardium is spongy or trabecular. It is nourished entirely by the blood within its chambers passing through intertrabecular spaces which extend right out to the epicardium. The same is true of the ventricle of the heart of the amphibian, except that its bulbus cordis has a cortex of compact muscle with a vascular supply. In the heart of the reptile the proportion of compact cortical muscle is greater; the coronary vessels are more important; Thebesian veins are present.

The developing mammalian heart (the rabbit) is spongy, and early is nourished by blood contained in the intertrabecular spaces of the myocardium. Coronary veins appear later as outgrowths from the left horn of the sinus venarum and extend along the sulci. From them, branches spread over the surface of the myocardium, enter it, and communicate with the intertrabecular sinusoidal spaces. Outgrowths from the endo-

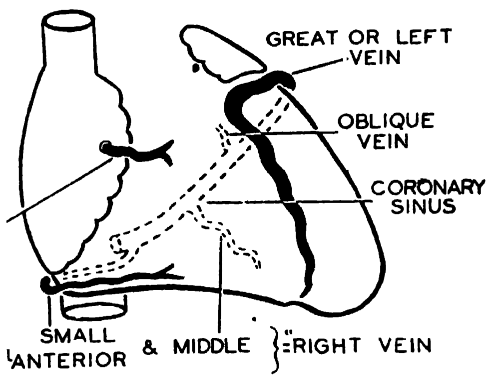


FIG. 572. The cardiac veins placed on figure 565.

cardium give rise to epicardial capillaries which connect with branches of the coronary veins (and probably with the coronary arteries also later) to form the *Thebesian veins* of adult anatomy; they also connect with each other The coronary arteries then sprout from the future aorta, spread over the heart, and unite with the capillary network already formed by the veins and intertrabecular spaces in the developing myocardium. With further development the intertrabecular spaces of the ventricles are for the most part reduced to capillaries and, being incorporated with the arteries and veins, persist as an integral part of the adult coronary circulation. The accompanying scheme (*fig. 573*), which

indicates how the human (mammalian) myocardium is irrigated, now becomes intelligible.

Numerous investigators, using media of different viscosities and at different pressures, have injected the coronary arteries, coronary veins, and Thebesian veins and seem to have established the facts that (a) when physiological saline solution or india ink is perfused through a coronary artery most (about 90 per cent) escapes into the lumen of the heart via the Thebesian veins, and very little passes through the capillaries to the coronary

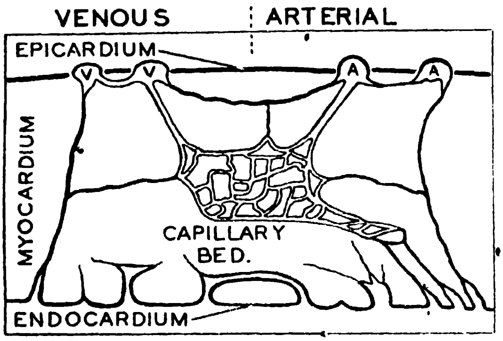


FIG. 573. Scheme of the myocardial circulation. (After Batson.)

sinus. (b) Similarly, when a vein is perfused most escapes by Thebesian veins and a little passes through the capillaries to the arteries. (c) A fluid too viscous to pass through the capillary bed will, when injected into an artery (or vein), escape into the lumen of the heart via the Thebesian veins. (d) A fluid too viscous to flow out through the arteries may yet, when injected into a coronary vein, enter the heart via the Thebesian veins. Evidently, then, the pathway from coronary vein via Thebesian veins to the lumen of the heart is wider than from coronary artery via Thebesian veins to the lumen, and this in turn is wider than the passage through the capillary bed. (e) It is found that when particles (e.g., carborundum), too large to traverse either the capillaries or Thebesian veins of the heart or the capillaries of the lung, are injected during life into the external jugular vein of the dog, they accumulate in large numbers in the coronary sinus and in the veins on the surface of the heart. To get there they must have taken a retrograde course in the veins (Batson).

The Collateral Circulation. (a) *Intrapericardial.* There are no end arteries in the heart. There are rich anastomoses in all layers of the heart; the main branches of the coronary arteries anastomose with each other, so do the precapillaries and the capillaries. Moreover, the anastomoses improve with age, the channels becoming wider, and in the epicardial fat they apparently increase in number. So, if one coronary artery (or branch) is slowly obliterated, a collateral circulation can be established.

(b) *Extrapericardial.* If both coronary arteries are obstructed, there is an extrapericardial collateral circulation to be called upon, but it may not effectively answer the call. Thus, injections of india ink into healthy coronary arteries in part follow the vasa vasorum and vessels in the tunica adventitia of the aorta as far as the diaphragm, and of the pulmonary arteries as far as the lungs. Other anastomosing twigs pass through the pericardium with the four pulmonary and two caval veins to anastomose with branches of the internal mammary, bronchial, and diaphragmatic arteries.

As the coronary sinus and veins of the heart have no adequate valves, it is not impossible that blood may take a retrograde course in the veins, irrigate the myocardium, and enter the lumen of each of the four chambers via the Thebesian veins.

Note on the Development of the Heart.

The following facts assist in the appreciation of the relations of the various parts of the heart and explain certain anomalies:

Elongation of the Tubular Heart. The primitive tubular heart received blood at its caudal end and discharged

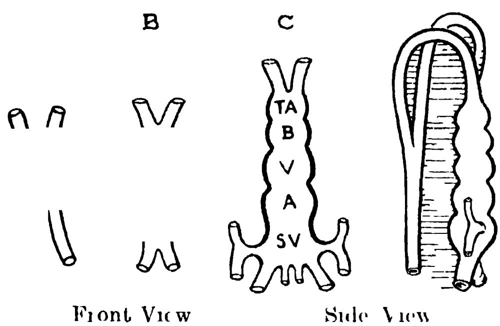


Fig. 574. Scheme of the development of the tubular heart.

it from its cephalic end. This tubular heart had *five sacculations*—the sinus venarum, atrium, ventricle, bulbus arteriosus, and truncus arteriosus (*fig. 574*). The constriction between the primitive atrium and ventricle becomes the coronary or atrio-ventricular sulcus. Just as the intestine has a dorsal mesentery, so the tubular heart had a *dorsal mesocardium.* The *transverse pericardial sinus* is the result of a perforation in the dorsal mesocardium. When the developing intestine became much too long for the peritoneal cavity, it became convoluted. When the cardiac tube became somewhat too long for the pericardial cavity, it formed an S-shaped loop (*fig. 575*). Its two caudal segments (sinus venarum and atrium) and the entering veins came to lie dorsal to the three cephalic segments of which the last (truncus arteriosus) divided to form the ascending aorta and the pulmonary artery. Hence, the **atria** and the entering veins of adult anatomy lie posterior to the ventricles and the emerging arteries (*fig. 576*). The **atria**, cramped as it were for space and prevented from enlarging forwards, **expand** laterally on both sides of the **truncus** (aorta and pulmonary artery of **adult** anatomy) and largely embrace it.

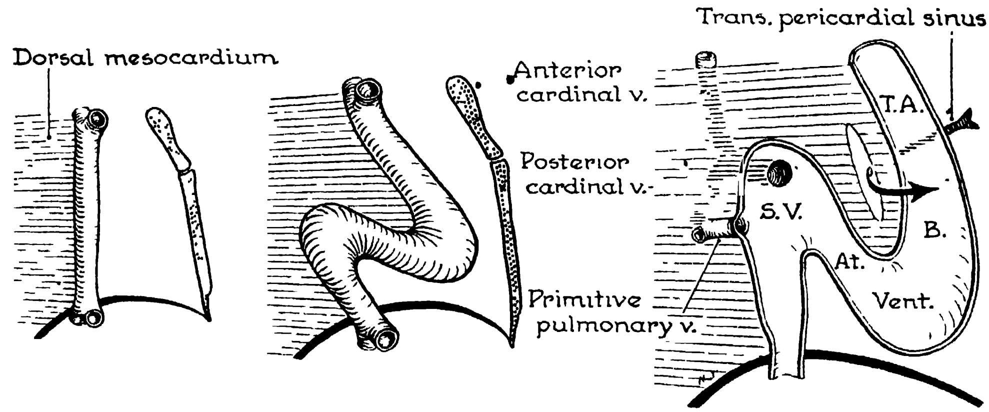


Fig. 575. The elongated tubular heart becomes "S-shaped".

Perforation of the Dorsal Mesocardium. In consequence of a perforation in the mesocardium, the transverse pericardial sinus appears and the truncus arteriosus finds itself enveloped in a tube or sleeve of visceral pericardium. Hence, when a septum divides the truncus into two, both resulting vessels (aorta and pulmonary artery) lie within a single pericardial sleeve in front of the transverse sinus.

THE OBLIQUE PERICARDIAL SINUS (*pp. 538, 550*).

THE SPIRAL SEPTUM IN THE TRUNCUS ARTERIOSUS. The fact that a spiral septum develops within the truncus explains the twisted courses of the pulmonary artery and ascending aorta around each other (*fig. 577*). The course of the spiral septum was such that its cardiac end bisected the right and left lateral cusps of the primitive four cusped valve of the truncus arteriosus; hence, the relative positions of the definitive cusps of the aortic and pulmonary valves (*fig. 578*).

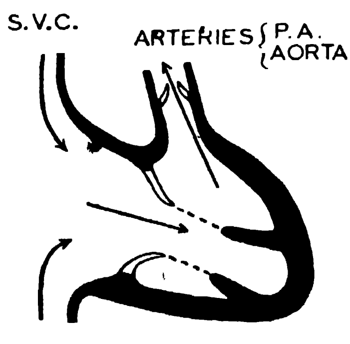


FIG. 576. Diagram of heart in sagittal section to show that the atria and entering veins are posterior to the ventricles and emerging arteries.

The upper end of the septum left the aorta connected to the upper 4 (or 5) paired primitive aortic arches, and the pulmonary artery connected to the 6th or lowest pair. That is why the pulmonary artery ends by bifurcating below the level of the definitive aortic arch (*fig, 592*).

THE AXIAL ROTATION OF THE HEART. The heart undergoes a slight rotation on its long axis, opposite in direction to the rotation of the stomach. In consequence of this, (a) the right atrium is conspicuous at the right margin of the heart and anteriorly; the left atrium is conspicuous posteriorly; (b) the right ventricle is largely in front and slightly inferior; the left ventricle is largely inferior and slightly in front; and, as will be seen later, (c) the interatrial and interventricular septa come to face forwards and to the right (and backwards and to the left); so do both cusps of the mitral valve and the septal cusp of the tricuspid valve, for these 3 cusps are approximately parallel to the septum; and lastly (d) the

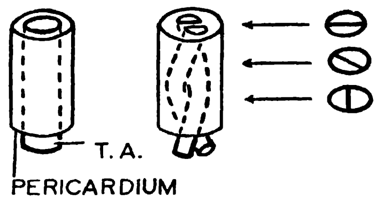


FIG. 577. The spiral septum within the truncus arteriosus explains the twisted courses of the aorta and pulmonary artery.

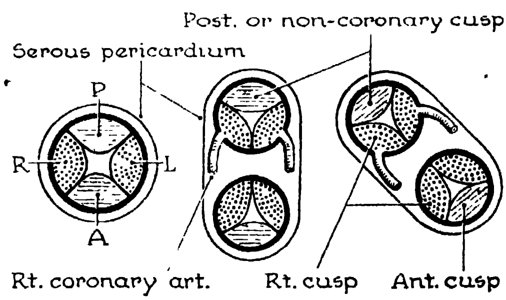


FIG. 578. The 4 cusped valve of the truncus splits to form 2 valves, each with 3 cusps. Axial rotation occurs, but it need not affect the nomenclature.

cusps of the valves of the two great arteries, which were originally disposed anteriorly, posteriorly, to right, and to left (*fig. 578*), share in the rotation. They undergo, so to speak, a "magnetic deflection" and cease to face the four points of the compass.

TERMINOLOGY OF THE CUSPS. Various and often confusing names are given to the cusps of the aortic and pulmonary valves. It is simplest and highly convenient to refer to the 3 cusps (and

sinuses) of the aortic valve as the *right* and *left coronary cusps* (and sinuses) and the *non-coronary cusp* (and sinus)—for the right and left coronary arteries arise from the right and left "deflected or rotated" sinuses. The cusps (and sinuses) of the pulmonary valve are the "deflected or rotated" right, left, and anterior cusps (and sinuses). These terms have the advantage of expressing the embryological values of the cusps, and from them the topographical positions are easily deduced without taxing the memory.

returns by either the (right) s. v. cava or (right) i. v. cava to the right side of the sinus venarum, and from it passes to the right side of the heart, the left side of the sinus venarum atrophies (or rather ceases to develop pari passu with the right side) and is known as the *coronary sinus*. So, though the coronary sinus plays the part of a vein, it was not as a vein that it developed, but as a part of the heart, and even in the adult, cardiac muscle covers it.

If the left s. v. cava persists—and a specimen of such may be seen in every

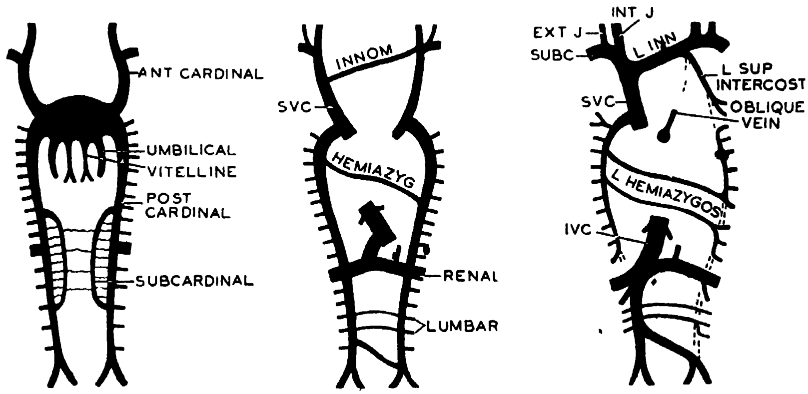


FIG. 579. The veins: (A) Six veins enter the sinus venarum (B) Cross communication appear. (C) Only two of the six veins survive. They become the caval veins. (The pulmonary veins join the heart later.) (After Arey.)

THE VEINS. Of the six veins entering the primitive sinus venarum (right and left—vitelline, umbilical, and common cardinal) two survive, (a) the prehepatic portion of the right viteoline vein and (b) the right common cardinal vein (*figs. 579, 258*). These become the terminal portions of the i. v. cava and s. v. cava respectively. The other four lose their connections with the heart. The establishment of cross communicating veins—(left common iliac, left lumbar, left renal, left hemiazygos, and left innominate)—render them unnecessary.

Now, since the systemic venous blood

museum—it joins the coronary sinus; and on its way it bears the same relation to the left pulmonary vessels as the right s. v. cava bears to the right vessels, i.e., it crosses in front.

Chambers of the Heart. The Right Atrium. EXTERIOR. The right atrium extends from the orifice of the s. v. cava behind the third right costal cartilage to the orifice of the i. v. cava behind the sixth right costal cartilage. It forms the whole of the rounded right border of the heart; it also forms parts of the sternocostal and posterior surfaces (*fig. 564*). It is demarcated from the right ventricle

by the atrio-ventricular or coronary sulcus. The parietal pericardium intervenes between it and the right phrenic nerve. It developed from the right half of the sinus venarum and right half of the primitive atrium which merged to form a single chamber. The line of mergence is indicated on the surface by a groove, the *sulcus terminalis*, which extends, as you would expect, from the front of the s. v. cava to the front of the i. v. cava.

INTERIOR. On opening the somewhat cubical atrium, a pronounced ridge, the and is situated on the interatrial septum, which forms the medial wall of the right atrium. The right atrio-ventricular orifice, usually called the *tricuspid orifice*, takes the place of an anterior wall (*fig.* 576). The *orifice of the coronary sinus* opens between the orifice of the i. v. cava and the tricuspid orifice. It is guarded by a fold, detached from the valve of the i. v. cava. This fold, often perforated like a piece of lace, is known as the *valve of the coronary sinus*. If the handle of the knife or tip of the forceps

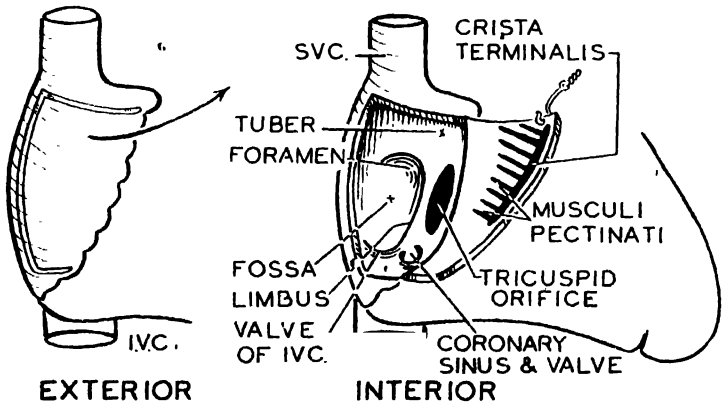


FIG. 580. The right atrium. Exterior and interior.

crista terminalis, is seen to correspond in position to the sulcus terminalis on the exterior. The portion of the atrium behind the crista is smooth. It developed from the sinus venarum. The portion in front is trabeculated. It developed from the primitive atrium. The parallel ridges running forwards from the crista terminalis towards the auricle are the *musculi pectinati* (*fig.* 580). From the lower end of the crista terminalis a prominent fold of endocardium, the *valve of the i. v. cava*, passes in front of the orifice of the i. v. cava to become continuous with the crescentic margin of a depression, the *fossa ovalis*. The fossa ovalis is the size of a thumb nail be passed up the i. v. cava from its cut abdominal end, it will be arrested by the crescentic upper margin of the fossa ovalis. But in about 25 per cent of cases it will pass onwards through a valve-like slit in the septum, called the *foramen ovale*, into the left atrium. This is the course much of the blood took until birth.

The History of the Foramen Ovale is this: an antero-posterior partition, called the *septum primum*, grew downwards from the roof of the primitive common atrial chamber and divided it into right and left atria (*fig.* 581). But, before its lower end fused with the anterior and posterior endocardial cushions that divided

the common primitive atrio-ventricular orifice into the tricuspid and mitral orifices, its connection with the roof was severed, giving it a free upper edge. A second partition, the *septum secundum*, then grew downwards from the roof of the right atrium (and therefore on the right of the septum primum) till its free lower edge overlapped the free upper edge of the septum primum. It becomes the crescentic upper margin of the fossa ovalis. Until birth the blood from the i. v. cava is largely directed through this valve-like foramen. After birth the pulmonary circulation is established, the

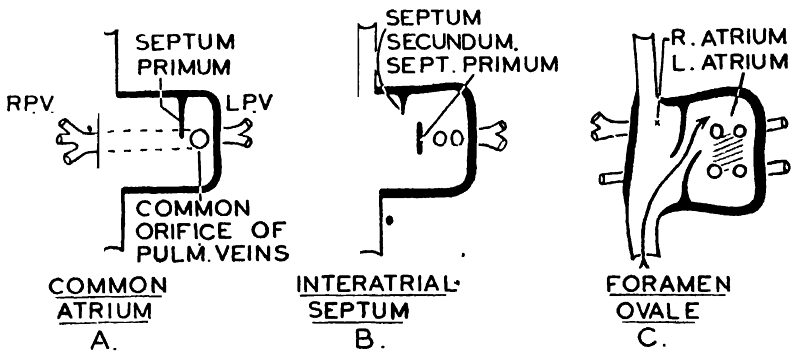


FIG. 581. Development of left atrium; incorporation of the stem of the primitive "common pulmonary vein": The history of the foramen ovale.

pressure in the left atrium rises, and the flap valve is closed. In about 75 per cent of individuals the opposed surfaces fuse. In 25 per cent of individuals the edges of the primary and secondary septa overlap but fail to fuse; so, the foramen is patent anatomically, though closed physiologically (*fig. 48*). Rarely the edges of the septa fail to meet; the result is a foramen patent both anatomically and physiologically. In consequence, the pulmonary circulation is disturbed and the child may be congenitally blue in colour.

The Left Atrium forms two-thirds of the posterior surface of the heart and it peeps round the left border behind the second left intercostal space (*fig. 568*). It is demarcated from the left ventricle below by the atrio-ventricular or coronary sulcus. The right and left pulmonary veins open into it near its right and left margins, and between them is the oblique pericardial sinus. The pericardium separates the left atrium from the oesophagus and descending aorta posteriorly (*fig. 604*).

There is little to see inside this atrium. It is well, therefore, to preserve it unopened till late, because this helps to keep ones bearings. The auricles are trabeculated; the rest of the cubical cavity is smooth. The mouths of the four pulmonary veins open on the posterior wall; the left atrio-ventricular or *mitral orifice* replaces the anterior wall. The interatrial septum is set obliquely, hence ⅔ of the left atrium and only ⅓ of the right atrium lie posteriorly (*fig. 604*). The foramen ovale, when patent, can be seen.

History. The trabeculated part of the left atrium is derived from the primitive atrium. The smooth part is formed thus: the primitive pulmonary vein, draining both lungs, passed forwards through the dorsal mesocardium and joined the left atrium (*fig. 581*). Its stem and primary branches then became incorporated in the definitive left atrial wall and formed its

smooth part in the same way as the stems of the Wolffian ducts formed the trigone of the bladder. From this it will be understood that the number of pulmonary veins may be decreased or increased. Hence, the left atrium, like the right atrium, has a double origin. The left limb of the sinus venarum becomes the coronary sinus, and does not contribute to the formation of the left atrium.

The pericardial cavity extends upwards into the widening dorsal mesocardium, which now transmits the two right and two left pulmonary veins, and separates them. The recess thus formed is the

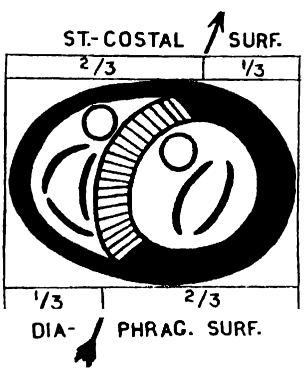


FIG. 582. Transverse section of ventricles—key sketch. (Viewed from below.)

oblique pericardial sinus. Clearly, it corresponds on the outside of the left atrium to the smooth part of the inside (*fig. 581, C*).

The Ventricles lie in front of the atria (*fig. 576*). They form the apex of the heart, the entire inferior margin and diaphragmatic surface, most of the left margin and sterno-costal surface, and a trivial part of the posterior surface below the coronary sinus. On cross-section it is seen that the thickness of the walls of the two ventricles is proportional to the amount of work each has to do. Before birth, both chambers pumped blood into the aorta—the left ventricle directly, the right ventricle via the ductus arteriosus—and their walls were equal in thickness. After birth, the left ventricle is the pump of the systemic system; the right ventricle of the pulmonary system, and the ratio of their thickness is 3:1. This explains why the interventricular septum bulges into the right ventricle, and why the cavity of the left ventricle is circular on section and that of the right ventricle crescentic. You might expect that the interventricular septum would occupy the median plane and that the two ventricles would present equally to the front; but the rotation of the heart to

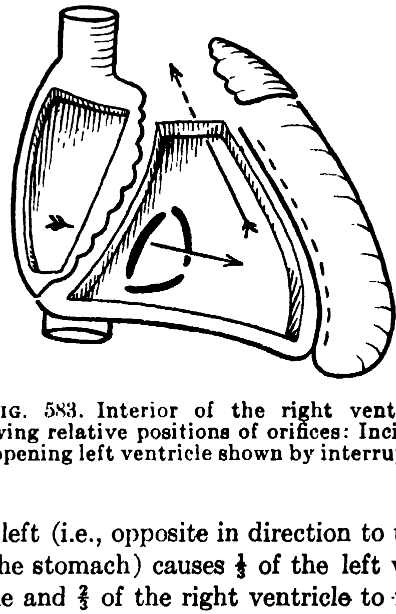


FIG. 583. Interior of the right ventricle showing relative positions of orifices: Incision for opening left ventricle shown by interrupted line.

the left (i.e., opposite in direction to that of the stomach) causes $\frac{1}{3}$ of the left ventricle and $\frac{2}{3}$ of the right ventricle to face anteriorly, and $\frac{2}{3}$ of the left ventricle and $\frac{1}{3}$ of the right ventricle to face inferiorly. This is indicated by the positions of the anterior and inferior interventricular sulci (*fig. 582*).

The *cavity* of the right ventricle is triangular (*fig. 583*); the cavity of the left ventricle is conical. The *entrances* or atrio-ventricular orifices are posterior; the *exits* or orifices of the aorta and pulmonary artery are superior; so, the blood pursues a V-shaped course within

the ventricles. Each exit is on the septal side of the entrance. Except near the exits, the ventricular walls are lined with muscular bundles, *trabeculae carneae.* Some are merely elevated *ridges,* others are attached at both ends like *bridges,* and others form finger-like projections, the *papillary muscles.* One bridge, the *moderator band,* passes from the septum to the base of the right *anterior papillary muscle.* In each ventricle an anterior and an inferior papillary muscle rise from the corresponding walls. Those on the left side are larger than those on the right. In the right ventricle small papillary muscles rise from the septum also.

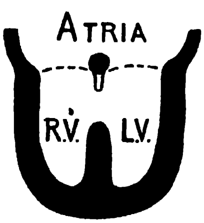


Fig. 584. Development of the interventricular septum.

From the apices of the papillary muscles fibrous cords, *chordae tendineae,* pass to the cusps of the atrio-ventricular valves.

The portion of the right ventricular cavity preceding the pulmonary artery is smooth, is derived from the bulbus cordis, and is called the *infundibulum.* The corresponding portion of the left ventricle is smooth, largely fibrous and non-distensible, and called the *aortic vestibule.* It cannot contract and empty; neither can it dilate. The thinnest part of the muscular wall of the left ventricle is at the apex.

The Interventricular Septum is fleshy except at its uppermost part where an area, the size of a thumb nail, is membranous. The two parts have different origins. The *fleshy part* is an upgrowth from the apex; the *membranous part* a downgrowth from the interatrial septum and right side of the root of the aorta (*fig. 584*). Failure of the fleshy and membranous parts to fuse results in a "patent" interventricular septum. The *pars membranacea septi* is best seen from the right side after removing the septal cusp of the tricuspid valve. It can be felt between the finger and thumb placed one in each ventricle (*fig. 588*).

The Arterio-ventricular Valve on the right side is *tricuspid*; on the left, *bicuspid.* Vesalius likened the bicuspid valve to a bishop's mitre, hence the left valve is referred to as the *mitral valve.* The chordae tendineae are attached to the edges and

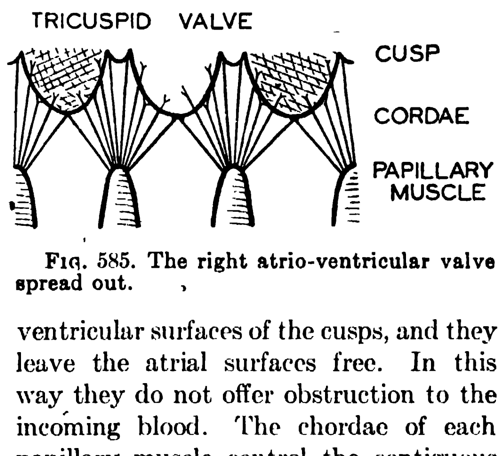


Fig. 585. The right atrio-ventricular valve spread out.

ventricular surfaces of the cusps, and they leave the atrial surfaces free. In this way they do not offer obstruction to the incoming blood. The chordae of each papillary muscle control the contiguous margins of two cusps (*fig. 585*). Hence, there are two papillary muscles on the left side and three, or groups of three, on the right. The bases of the cusps unite to form a short cuff which is attached to the fibrous atrio-ventricular orifice. The margins of the cusps are dentate where the chordae are attached. The edges and surfaces of the cusps must meet when the valve is closed, otherwise the valve will leak. Therefore, the two cusps of the mitral valve are parallel to each other; they are also parallel to the septum; and also to the septal cusp of the tricuspid valve. *All four structures* face forwards

and to the right, and backwards and to the left (*figs. 582, 587*). The cusps of the mitral valve may be referred to as right and left, or as septal and marginal. Because the right or septal cusp is interposed between the atrio-ventricular and the aortic orifice, it is commonly referred to as the *aortic cusp.* The current of blood passes over both surfaces of the aortic cusp and the chordae are largely confined to its margin.

Structure. The papillary muscles, chordae tendineae, and cusps of the atrioventricular valves are developed from the (primitive) muscular spongework of the heart (*fig. 586*); and in fetal life the cusps are both fleshy and vascular. Before birth the muscle fibers and the vessels undergo regression. In adult life muscle fibers are found in the bases of all five cusps; they include smooth nonstriated fibers.

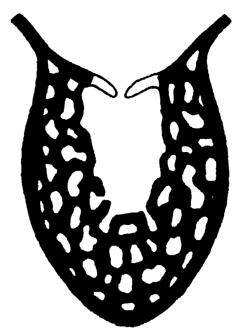


FIG. 586. The primitive muscular spongework of the ventricles.

Blood vessels do not occur in the cusps of healthy human heart valves, except for 1 mm.—3 mm. at their bases. Inflamed valves, however, do become vascularised. When valves, which are apparently healthy, are found to be vascularised, it is probable that they have recovered from an inflamatory infection (e.g., rheumatic fever) and that the vessels have not completely receded. (Gross; Harper.)

The valves of certain domestic animals (horse, dog, cat, ox, sheep, goat, and pig) normally contain vessels; they are vascularised. The valves of the rabbit, like those of man, are not vascularised.

Surface Anatomy of the 4 Cardiac Orifices guarded by functioning valves—pulmonary, aortic, mitral, and tricuspid. These lie behind the sternum on an oblique line joining the 3rd left sternocostal joint to the 6th right: thus, the *pulmonary orifice* is deep to the left 3rd sternocostal joint; the *aortic orifice,* being slightly lower, more medial, and more posterior, is behind the sternum at the level of the 3rd intercostal space; the *mitral orifice,* is still lower and more medial at the level of the 4th costal cartilage; and the *tricuspid orifice* is on the right of the median plane at the level of the 4th and 5th spaces.

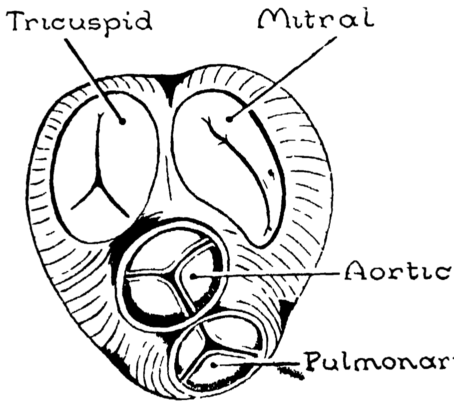


FIG. 587. The four orifices guarded by valves, showing the cusps, also the superficial muscle layer of the ventricle. (After Spalteholz.)

Structure of the Heart. THE SKELETON OF THE HEART. A fibrous ring surrounds each of the four orifices guarded by valves (*fig. 587*). The aortic ring is the strongest and is like a cuff. Without the rings the orifices would stretch and the valves be rendered incompetent. The

rings are joined to each other, as shown in figure 588, and to the pars membranacea septi. In some animals, e.g., the sheep, there is a bone, *os cordis*, in the right triangular fibrous area (trigonum fibrosum).

MUSCULATURE. The heart muscle, *myocardium*, is clothed externally with serous pericardium, *epicardium*, and is lined internally with *endocardium*, and subpericardially there may be much fat, especially in the sulci.

THE ATRIAL MUSCULATURE. The atrial walls are translucent. The superficial muscle fibers run transversely; the deep fibers arch over the atrium from front to back and are attached to the skeleton by both ends; other fibers encircle the mouths of the great veins.

THE VENTRICULAR MUSCULATURE (*figs. 589, 590, 591*). The ventricular *musculature* is composed of three layers—(a) superficial, (b) middle, and (c) deep.

The Superficial Layer. If you twist your coat sleeve to the left, the spiral creases thereby produced will indicate the direction in which all superficial heart fibers run, whether at the front, sides, or back of the heart.

The Middle Layer. The *middle layer of the left ventricle* is a cylinder that surrounds the cavity of the left ventricle. It is the thickest and most basic layer of the whole heart. This cylindrical left middle layer is distinguished by possessing a free lower border. The fibers forming this lower border turn or roll upon themselves like the fibers of the lower border of the Pectoralis Major.

Now, all fibers of the heart arise from the heart skeleton, and eventually they return to be inserted into the heart skeleton. Those of the middle layer arise from around the left atrio-ventricular ring and run from left to right across the front of the heart to be inserted around the pulmonary ring, conus tendon, and septal side of the aortic ring.

The *middle layer of the right ventricle.* Its fibers arise from the left a-v. ring, run around the back of the left ventricle to the posterior interventricular sulcus where (a) some run vertically downwards in the interventricular septum, while (b) others run round the ventricle to meet and interdigitate with the septal fibers at the anterior interventricular sulcus, and from there they continue over the anterior surface of the left ventricle.

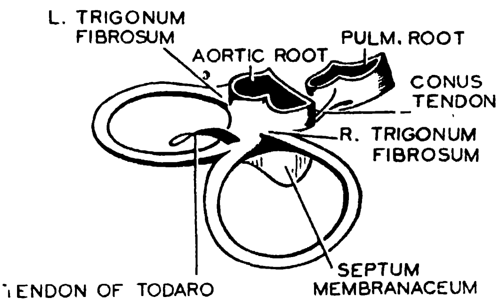


FIG. 588. The skeleton of the heart. (After Todaro.)

The Deep Layer. The deep layer is a direct continuation of the superficial layer which, after running obliquely downwards like a twisted sleeve on the superficial surface of the middle layers, turns around the lower border of the cylinder (or penetrates to the deep surface of the right ventricle's middle layer) and then ascends to gain attachment to the heart skeleton either directly, or indirectly through the papillary muscles, chordae tendineae, and valve cusps.

As the superficial fibers are turning or twisting around the lower border of the cylinder, they skirt it for a third of a circle before proceeding upwards as the fibers of the deep layer. As the mouth of the cylinder becomes more and more filled by these entering fibers, the orifice becomes progressively narrower and the third of a circle, which the most super-

ficial fibers describe, becomes diminishingly smaller until ultimately the apex is represented by a fibrous pinpoint.

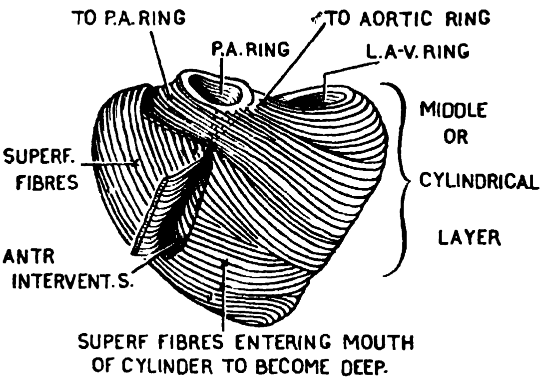


Fig. 589

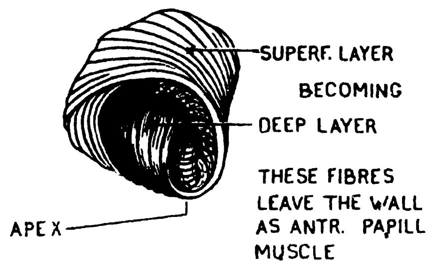


Fig. 590

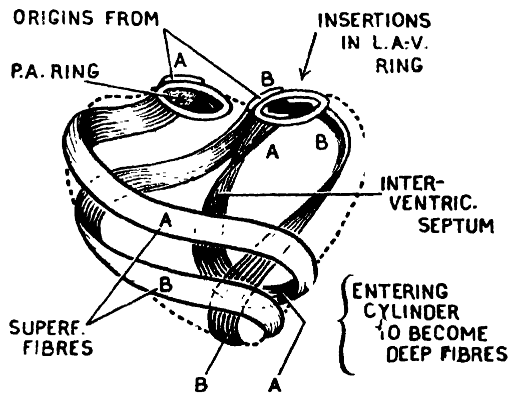


Fig. 591. Dissections of the ventricles of the heart of the sheep. (By B. Leibel).

Note that (a) the ascending fibers of the deep layer take a direction at right angles to the descending fibers of the superficial layer. If, therefore, a block of muscle is removed from any part of the ventricular wall and examined, the fibers of the inner and outer surfaces are seen to run at right angles to each other. (b) Both ends of all ventricular fibers are attached to the heart skeleton, thereby insuring that the aorta and pulmonary artery shall not be shot from the heart, like a cork from a bottle, during ventricular systole. (c) Contraction of the superficial and deep layers serves to shorten the ventricles. Contraction of the middle layer results in narrowing the lumina of the ventricles. (d) Further, owing to its attachment to the pulmonary ring, etc. the middle cylindrical layer on contracting tends to pull the left ventricle forwards and to the right; so, in systole the heart rotates anteriorly and to the right and strikes the chest wall. (e) And still further, the ventricles are not emptied as, for example, the urinary bladder is emptied, but the blood is wrung from the cavities like water from a cloth. (This description is based on work done by B. Liebel.)

The Conducting System consists of: (a) The *sinu-atrial node* initiates the heart beat. It is a collection of peculiar, longitudinally striated cells, 2 cm. long by 2 mm. wide, situated along the upper end of the sulcus terminalis. It is supplied by the right coronary artery and right vagus nerve. (b) The *atrio-ventricular node* has the same structure and is situated in the interatrial septum beside the mouth of the coronary sinus. It also is usually supplied by the right coronary artery (and the anastomoses are free and ample) but by the left vagus nerve. (c) The *atrio-ventricular bundle* (of His) is a pale bundle of peculiar muscle fibers about 2 mm. thick, enveloped in a loose sheath. It extends from the node, through the fibrous part of the skeleton, to the interventricular

septum. It skirts the hinder part of the membranous septum, and at the upper part of the muscular septum it divides into right and left branches. These descend in their sheaths, subendocardially, to the bases of the papillary muscles, that of the right side passing through the moderator band. In the properly prepared heart the whole system is easily injected with india ink and water. *Purkinje fibers* occur subendocardially in connection with the fibers of the a-v. bundle.

NERVE SUPPLY TO THE HEART. (a) *Vagus*, via two cervical cardiac branches and by branches arising from the vagus and the recurrent laryngeal within the thorax. (b) *Sympathetic*, via three cervical cardiac branches (relayed in the cervical ganglia) and five thoracic cardiac branches (relayed in the upper five thoracic ganglia). The cardiac plexuses are described on page 562.

Distribution. Branches of the *deep plexus* find a ready path in front of and behind the (right) pulmonary artery to the back of the atria, which they supply, the right nerves controlling the sinu-atrial node; the left nerves the atrio-ventricular node. They also pass forwards, mainly on the sides of the pulmonary artery, and as *coronary plexuses* are distributed with the coronary arteries to the ventricles. The branches of the *superficial cardiac plexus* communicate with the deep plexus and they descend in front of the stem of the pulmonary artery to join the right coronary plexus. The cardiac plexuses can easily communicate with the anterior pulmonary plexuses by branches which run laterally along the pulmonary arteries.

The vagal fibers are cardio-inhibitory; the sympathetic fibers are cardio-accelerator, vaso-dilator, and sensory.

THE SUPERIOR MEDIASTINUM

Notes on the Development of the Great Arteries. In the embryo, the thoracic contents are disposed symmetrically on the two sides; in the adult, this identical bilateral symmetry is lost, largely in consequence of the disappearance of certain veins from the left side of the body and of certain arteries from the right side. Clearly, if you would appreciate the relations of the superior and posterior mediastina in the adult, you should have some knowledge of the symmetrical arrangement in the embryo. Without this knowledge the anatomy of the region is unintelligible. The facts are simple and interesting; they explain many relationships and most of the common anomalies.

The Veins. The disappearance of the left s. v. cava was rendered possible by the establishment of certain cross communications between the right and left veins, as described on page 547 (*fig. 579*).

The Arteries. In the embryo, six primitive aortic arches, which are comparable with, though not identical with, the gill vessels of the fish, pass through the six visceral (branchial) arches on each side of the neck. (A) They connect the right and left primitive ventral aortae with the corresponding right and left primitive dorsal aortae, which fuse to form the descending thoracic aorta (*fig. 592 A*). (B) The vagus or tenth cranial nerve descends on the side of the pharynx and esophagus (or on the side of the trachea, after it is formed) and is separated from them by, and only by, the six primitive aortic arches. (C) The recurrent laryngeal nerve on each side recurs below the sixth primitive arch to supply the larynx, upper part of the oesophagus, and the future trachea (*fig. 592 B*). (D) It is on the IV, V, and VI pairs of primitive

aortic arches and on the adjacent parts of the ventral and dorsal aortae that your interest is centered at the moment. Of these arches the IV pair belongs to the systemic circulation; the V pair is transient and need not be mentioned again; the VI pair may be called, and should in any case be thought of as, the *right* and *left pulmonary arches*, because, after the spiral splitting of the truncus arteriosus into the ascending aorta and pulmonary VI right arch, which is thereby rendered useless, disappears also. The left arteries, having now to do double duty, enlarge. The dorsal part of the VI left arch is the ductus arteriosus. It is utilized to deflect part of the circulation from the lungs during fetal life. At the time of birth it is a large vessel; after birth it becomes a fibrous cord, called the lig. arteriosum. (F) The *definitive aortic arch* has a four-fold origin from: half the

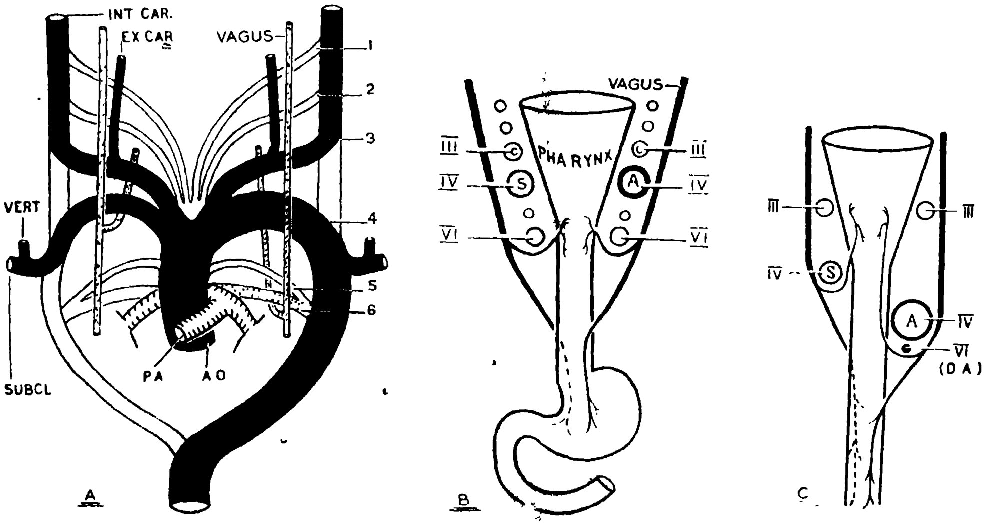


FIG. 592. (A) The 6 paired primitive aortic arches. (B) Coronal section of A showing that the arches separate the vagus nerves from the digestive tract. (C) A later stage of B explaining the courses of the recurrent laryngeal nerves.

artery, this pair remains connected to the pulmonary artery and unites it to the respective dorsal aortae. From each VI or pulmonary arch branches sprout into the corresponding lung; thereafter, the ventral portion of each VI arch becomes the stem of the corresponding right and left pulmonary artery of adult anatomy. (E) In man a certain economy is early exercised in the paired primitive aortic arch system, two pathways not being retained where one would suffice. Thus: (a) the portion of the right primitive dorsal aorta caudal to the III right arch disappears and (b) the dorsal end of the truncus arteriosus, part of the left primitive ventral aorta, the entire IV left primitive aortic arch, and part of the left primitive dorsal aorta. (G) The *innominate artery* is derived from the right primitive ventral aorta. It is equivalent on the right side to the part of the definitive aortic arch lying between the origins of the innominate and left common carotid arteries; evidently it is much elongated. The right subclavian artery has greater value than the left subclavian artery because it includes the IV right aortic arch. (*See fig. 715.*)

Reptiles and Amphibia (e.g., the frog)

retain both a right and a left definitive aortic arch; birds retain a right arch; whereas mammals, including man, retain a left arch (*fig. 593*). In rare instances man retains the early embryonic or symmetrical state of the frog, having both a right and a left aortic arch. Note particularly from the diagrams (1) that such a double aortic arch completely encircles the trachea and oesophagus—they lie within an arterial ring; (2) that the heart and ascending aorta lie in front of the oesophagus and trachea; (3) that the descending aorta lies behind the oesophagus; (4) that the aortic arches pass backwards across the sides of the trachea and oesophagus, and arch over and descend behind the bronchi and roots of the lungs; and (5) that 4 vessels—right and left common carotid, and right and left subclavian arteries—proceed from the arterial ring.

The asymmetrical results consequent upon the disappearance of the caudal segment of the right primitive dorsal aorta are: (1) The left aortic arch enlarges and displaces the oesophagus slightly and the trachea markedly to the right. Commonly it indents the lower end of the trachea and constricts the esophagus. (2) The oesophagus lies to the right of the aortic arch and beginning of the descending aorta. (3) The innominate artery, derived from the right ventral aorta, is elongated or drawn out. (4) The left recurrent laryngeal nerve recurs around the ligamentum arteriosum (VI arch) which is overshadowed by the enlarged definitive left aortic arch. The right recurrent laryngeal nerve, in the absence of a right ligamentum arteriosum, recurs around the right subclavian artery (IV arch). In other words, when the heart descends and the neck elongates, the recurrent nerves are dragged down by the lowest persisting aortic arches. In verification of this, note that in cases where the right IV arch (i.e., the stem of the subclavian artery) is absorbed and the arterial channel to the upper limb is maintained by the caudal part of the right dorsal aorta (which passes posterior to the oesophagus and trachea) the right recurrent laryngeal nerve arises high in the neck and passes directly to the larynx. (5) The vagi are held away from the pharynx, trachea, and oesophagus by the primitive aortic arches

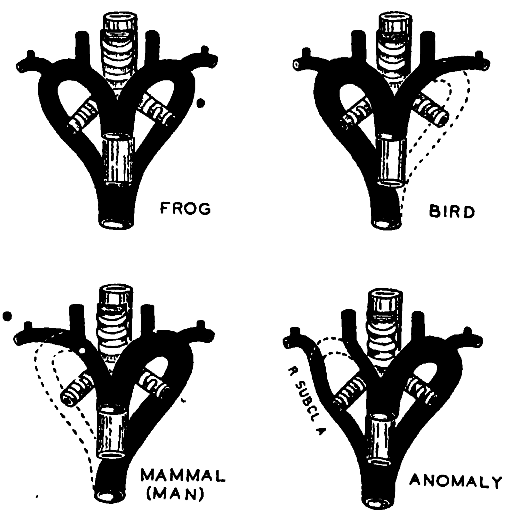


FIG. 593. Schemes of the aortic arch.

and cannot make direct contact with them until the last arch is crossed. The last arch on the left side is the ligamentum arteriosum (VI) and on the right side, the subclavian artery (IV).

Boundaries of the Superior Mediastinum. The study of the superior and posterior mediastina is simple to those who have followed the descriptions of the mediastinal pleurae given on pp. 513–520 and who appreciate the vascular economics, just described, that result in the loss of bilateral symmetry.

The superior mediastinum is the portion of the mediastinum above the level

of the pericardium (*fig. 536*). *Behind*, it is bounded by the bodies of the upper four thoracic vertebrae, intervertebral discs, anterior longitudinal ligament, and the Longi Cervicis which extend downwards to the upper two vertebral bodies. *In front* are the manubrium, and two strap-like depressor muscles of the larynx on each side. Of these, the diverging lower ends of the Sterno-hyoids arise from the back of the sterno-clavicular joint, and from the adjacent parts of sternum and clavicles (*fig. 667*); the converging lower ends of the Sterno-thyroids

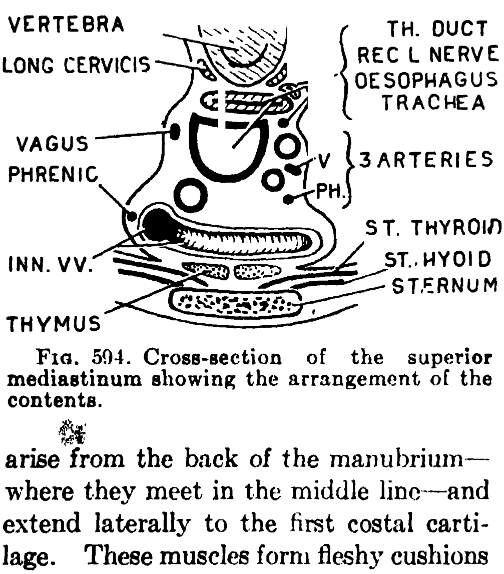


FIG. 594. Cross-section of the superior mediastinum showing the arrangement of the contents.

arise from the back of the manubrium—where they meet in the middle line—and extend laterally to the first costal cartilage. These muscles form fleshy cushions behind the sterno-clavicular joints and upper part of the manubrium. *On each side* is mediastinal pleura. An imaginary, nearly horizontal plane passing from the sterno-manubrial joint to the lower border of the body of the 4th thoracic vertebra lies at the upper limit of the pericardial sac and arbitrarily serves to separate the superior mediastinum above, from the anterior, middle, and posterior *mediastina—collectively* known as the *inferior mediastinum*—below

Contents. The various contents of this region were partially exposed from the sides when the mediastinal pleurae were examined. They are now to be examined from the front. They are:

(a) Retrosternal structures:
  1. Thymus.
  2. Great veins.

(b) Prevertebral structures:
  1. Trachea
  2. Oesophagus
  3. Left recurrent nerve } a "unit'
  4. Thoracic duct

(c) Intermediate structures:
  1. Aortic arch and its three great branches.
  2. Vagus nerves.
  3. Phrenic nerves.

Their general disposition is well revealed in a transverse section (*fig. 594*).

Retrosternal Structures

The Thymus in the adult is an elongated, encapsulated, fatty and lymphoid mass, lying in the loose tissue behind the manubrium sterni. On each side of it are the diverging anterior borders of the lungs and pleurae. Behind it are the left innominate vein and the aortic arch. The internal mammary vessels and the left innominate vein supply it. Little is understood of its function, of its lymph supply, or of the twigs supplied to it by the sympathetic, vagus, and phrenic nerves. The thymus has two asymmetrical lobes, which are easily separated from each other by blunt dissection.

Their early history accounts for their relationships. Arising from the right and left third pharyngeal pouches, each lobe migrates laterally between the primitive *cephalic aortic arches, comes into apposition* with its fellow of the opposite side in front of the pericardium, which

at this stage is situated in the neck. At birth its upper poles extend nearly to the lower poles of the thyroid gland (*fig.*

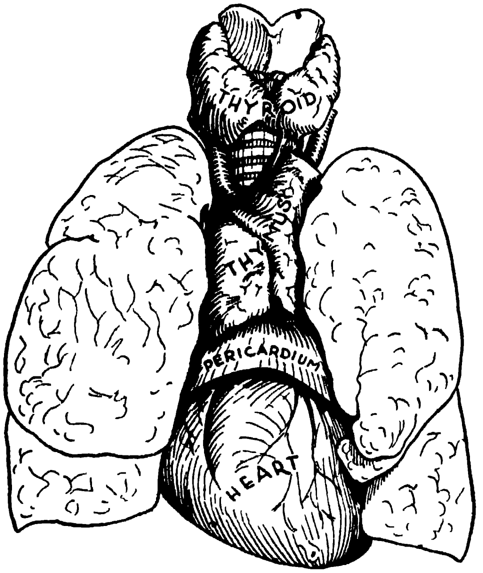


FIG 595. The thymus gland of a child.

puberty, after which it diminishes rapidly. In children who die a violent death it is found to be large; in children who have suffered from febrile diseases, even for a brief period, it is small.

The Great Veins. *The Left Innominate Vein* is a cross channel that deflects the blood from the left side of the head and neck, and from left upper limb towards the right or venous side of the heart. Formed by the confluence of the left internal jugular and left subclavian veins behind the sternal end of the clavicle, it passes behind the upper half of the manubrium to unite with the right innominate vein half way down the right side of the manubrium to form the s.v. cava (*fig. 596*). It is relieved from immediate contact with the sterno-clavicular joint and manubrium by the Sterno-thyroid and Sterno-hyoid muscles. The thymus gland also is in front of it. The aortic arch is below. The three great

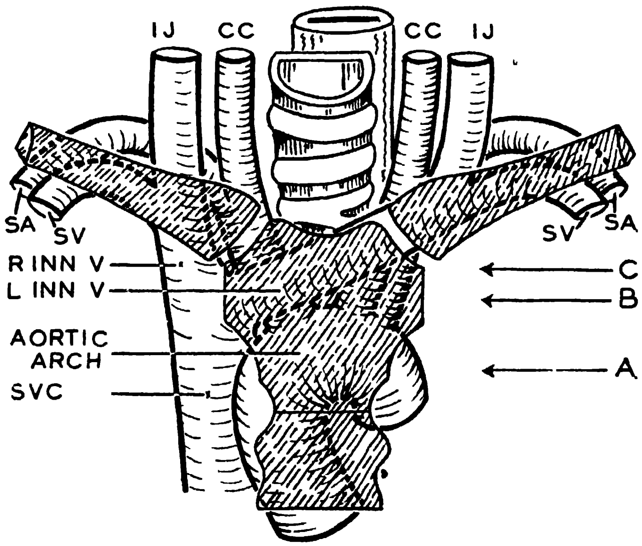


FIG. 596 Great vessels behind the manubrium (see figs 601 and 602).

595), while its lower ends cover the upper part of the pericardium.

It is relatively largest and most extensive at birth; absolutely it is largest at

branches of the arch and the four nerves that cross the arch are behind it. At its origin it grooves the left lung and is, therefore, in contact with the left pleura.

In youth and when engorged, its upper border rises above the suprasternal or jugular notch into the neck where it is in surgical danger.

The Right Innominate Vein is formed similarly behind the sternal end of the right clavicle. It descends vertically. After being joined by the left innominate vein, it continues vertically, as the *Superior Vena Cava*, to the 3rd right costal cartilage where it enters the right atrium. The s. v. cava projects beyond the right margin of the sternum and penetrates the pericardium obliquely. The intra-pericardial portion has been observed to lie in front of the root of the right lung and to be overlapped by the ascending aorta, the transverse pericardial sinus intervening. The extra-pericardial portion has the azygos arch entering it from behind at the upper border of the root of the lung (*fig. 538*). The right innominate vein and the extra-pericardial portion of the s. v. cava are covered with pleura and lung on three sides, i.e., in front, on the right, and behind. The ascending aorta and innominate artery are to the left. The right phrenic nerve and its vessels descend in contact with the right wall of this vertical venous channel.

Behind the junction of the subclavian and innominate veins the phrenic nerve enters the thorax; behind the innominate vein the vagus nerve enters the thorax;

The tributaries of the innominate veins fall into three groups:

(a) The internal jugular and subclavian veins.

(b) The thoracic or right lymph duct.

(c) Veins returning blood delivered by the branches of the subclaiavn artery (the suprascapular and the transverse cervical arteries excepted). They are: internal mammary, vertebral, and inferior thyroid veins and the vein from the 1st intercostal space. The left innominate vein also receives the left superior intercostal vein from 2nd and 3rd spaces, pericardial and thymic twigs (*fig. 681*).

The Prevertebral Structures

The oesophagus, trachea, left recurrent nerve, and thoracic duct run parallel courses through the superior mediastinum. They may be considered as a bundle or unit of 4 structures (*fig. 597*).

The *oesophagus* is directly applied to the bodies of the vertebrae of this region, the Longi Cervicis alone partly intervening. The *trachea*, throughout its entire course, both cervical and thoracic, is in turn directly applied to the front of the oesophagus. Below, it is indented and deflected to the right by the aortic arch. The *thoracic duct* ascends along the left border of the oesophagus. The *left recurrent nerve* arises from the vagus nerve on the left side of the aortic arch, turns tightly round the arch beyond the attachment of the ligamentum arteriosum, and encounters the lateral tracheo-bronchial lymph glands before ascending in the angle between the trachea and oesophagus.

The Trachea and Extra-pulmonary Bronchi. The trachea begins where the larynx ends at the lower border of the cricoid cartilage, on a level with the 6th cervical vertebra. Since it ends by dividing into right and left bronchi, on the plane between the superior and inferior mediastina, it follows that it crosses 5 vertebral bodies (1 cervical and 4 thoracic). By palpation you may easily determine on yourself that the cricoid is as far above the jugular notch (2″) as the sternal angle is below it (2″), making the total length of the trachea approximately four inches. Therefore, half the trachea lies within the confines of the superior mediastinum (*fig. 666, p. 650*).

It is constricted by the thyroid gland at its upper end, by the aortic arch at its lower end, and sometimes by the innominate artery on its right side retrosternally. It occupies the median plane except at its lower end where the aortic arch deflects it to the right. About 20 U-shaped rings of hyaline cartilage keep its lumen patent; the ring at the bifurcation has a *carina* or keel that supports the "crotch" of the trachea. Similarly shaped rings keep the extra-pulmonary and first inch of the intra-pulmonary bronchi patent.

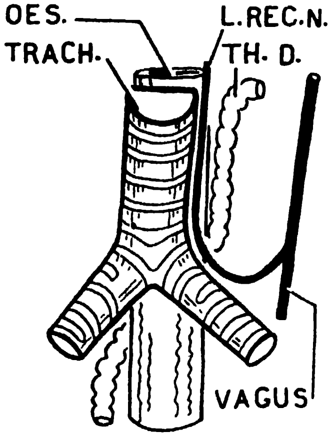


Fig. 597. The four prevertebral structures that run a parallel course and constitute a "unit."

Relationships of the Trachea (*fig. 598*). Throughout its entire thoracic course the oesophagus lies behind it, and the left recurrent nerve is in the angle between it and the projecting left border of the oesophagus. The aortic arch, lying behind the lower half of the manubrium, is in contact with the anterior and left aspects of the lower end of the trachea and of the other constituents of the "unit". The innominate artery (arising at the center of the manubrium), and the left c. carotid and left subclavian arteries (arising on the left of the center) wind round the trachea in semi-spiral fashion. In front of these is the left innominate vein. The right side is subpleural save where the innominate artery, right vagus nerve, and azygos arch intervene, thus: the right vagus (on entering the thorax between the beginning of the right innominate vein and the beginning of the right subclavian artery) gives off its recurrent branch and takes a subpleural course obliquely downwards and backwards, applied first to the right side of the innominate artery and then to the right side of the trachea. This it follows to the back of the right bronchus, where the azygos arch crosses lateral to it (*fig. 598*). The left side is excluded from contact with pleura by the left subclavian and left common carotid arteries and by the arch of the aorta. Further, the right and left parts of the deep cardiac plexus occupy the right and left tracheobronchial angles and communicate with each other around the lower end of the trachea; and the cardiac branches of the vagus and sympathetic that pass to the plexus run along the sides of the trachea.

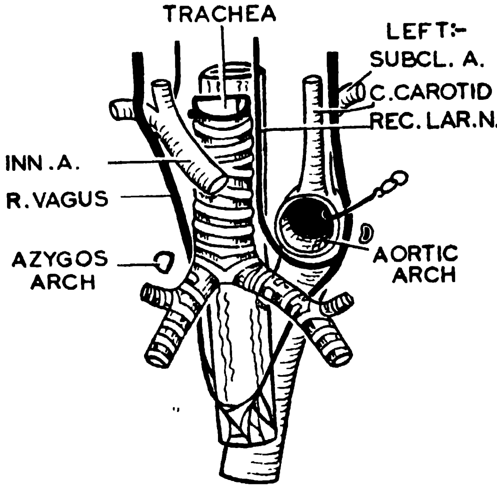


Fig. 598. The trachea and extra-pulmonary bronchi (lateral relations).

The Right and Left Extra-pulmonary

Bronchi (*fig. 599*). Of these the right bronchus is the larger (5:4) because it supplies the larger lung; it is the more vertical because the aortic arch deflects the trachea to the right. Hence, foreign bodies are more commonly aspirated into the right lung than into the left. The first branch of the right bronchus supplies the upper lobe of the right lung, passes above the right pulmonary artery (eparterial), and arises one inch or less from the trachea. The first branch of the left bronchus, supplies the upper lobe of the left lung, passes below the left pulmonary artery (hyparterial), and arises two inches from the trachea.

The bronchi arise in front of the oesophagus, to the right of the middle line, on the plane between superior and inferior mediastina. Their relations are those of the roots of the lungs. On each side, the angle between the trachea and the corresponding bronchus is occupied by lymph glands (lateral tracheo-bronchial); so also is the angle between the bronchi at the bifurcation of the trachea (inferior tracheo-bronchial glands) (*fig. 599*). In front of the glands the right and left pulmonary arteries run obliquely along the upper border of the atria. A stick has been passed through them.

The Cardiac Plexus surrounds the lower end of the trachea. It is divided into three subplexuses: *right* and *left deep plexuses*, which occupy the right and left tracheo-bronchial angles, and a *superficial plexus*, which lies above the bifurcation of the pulmonary artery, and therefore in the concavity of the aortic arch on the right of the ligamentum arteriosum. Therefore—and this is a fact to grasp—the different parts of the cardiac plexus lie along the upper borders of the right and left pulmonary arteries. The superficial plexus may be regarded as a detached part of the left deep plexus (*fig. 600*).

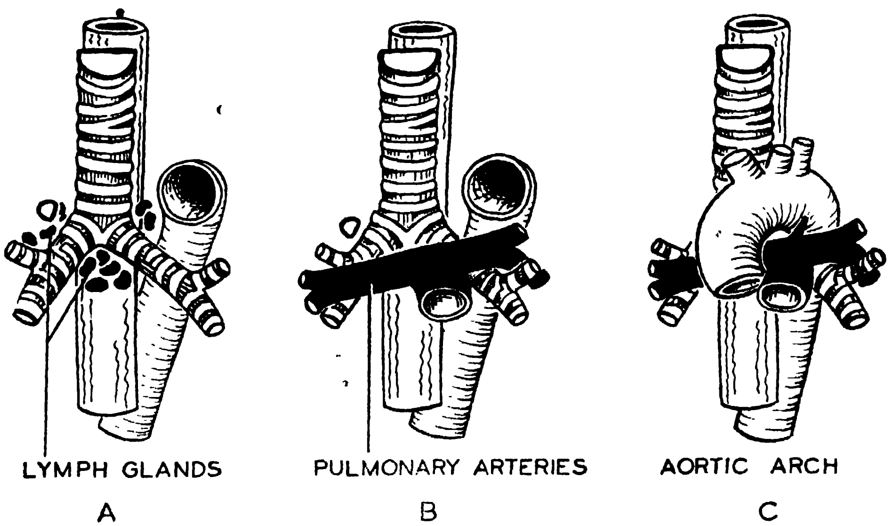


FIG. 599. Relations of the lower end of the trachea and of the extra-pulmonary bronchi, shown serially.

On each side, the plexus receives slender branches from the cervical and thoracic parts of the vagus and sympathetic. In the neck, an upper and a lower branch arise from the vagus below the origin of

the superior laryngeal nerve; in the thorax, one or more branches arise either from the vagus or from its recurrent branch. From each of the three cervical and upper five (in any case 2——5) thoracic sympathetic ganglia, branches pass to the respective sides of the plexus.

The nerves to the superficial cardiac plexus are the highest of the three left cervical sympathetic branches and the

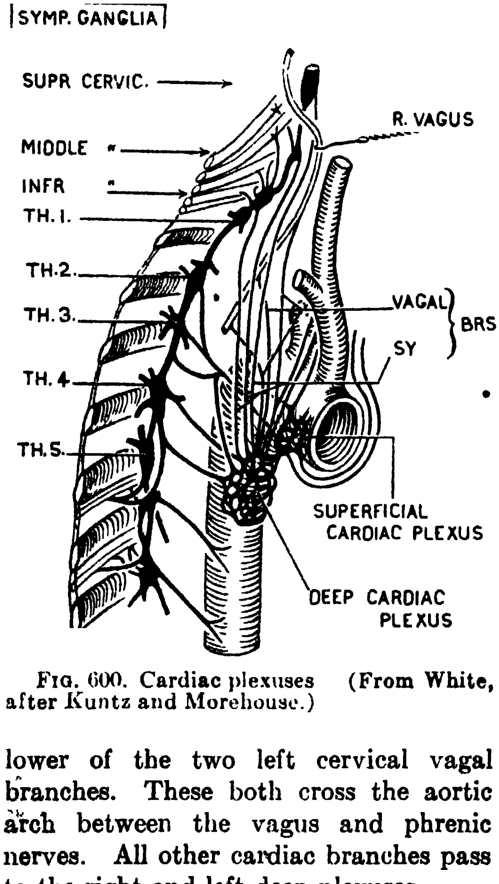


FIG. 600. Cardiac plexuses (From White, after Kuntz and Morehouse.)

lower of the two left cervical vagal branches. These both cross the aortic arch between the vagus and phrenic nerves. All other cardiac branches pass to the right and left deep plexuses.

It is a simple matter for the deep and superficial plexuses to send fibers laterally along the right and left pulmonary arteries to the corresponding anterior pulmonary plexuses and so to the lungs; to send other fibers downwards to the back of the atria of the heart; and others along the pulmonary artery and ascending aorta to the ventricles of the heart.

The cardiac plexus is the highest of the four prevertebral plexuses—cardiac, celiac, hypogastric, and pelvic. It supplies the heart and assists in the supply of the lungs.

Intermediate Structures

The Aortic Arch and its 3 Branches. As all the main and many of the detailed points about these vessels have already been noted at one time or another, the following paragraphs are in large measure a review.

The thoracic aorta is divided anatomically into 3 parts——the *ascending aorta*, the *arch of the aorta*, and the *descending thoracic aorta*. These occupy respectively the middle, superior, and posterior mediastina. To appreciate its course and relationships some knowledge of its development is essential (*p. 555*):

Developmentally, the aortic arch is formed from the IV left primitive aortic arch with the adjacent segments of the primitive ventral and dorsal aortae and part of the truncus arteriosus. It is, therefore, essentially a *left* aortic arch. *Topographically*, it is the part of the aorta that rises above the plane dividing the superior from the inferior mediastinum. It is placed behind the lower half of the manubrium. Its direction is backwards from the right border of the manubrium to the left border of the disc between 4–5 thoracic vertebrae. A bullet entering the chest from the front might almost traverse the arch (*fig. 601*).

Surfaces and Relations. It has four aspects: a left-anterior, right-posterior, convex upper, and concave lower. Its left-anterior aspect is touched by the right and covered by the left mediastinal pleura and lung, the thymus intervening.

It is crossed by four nerves (*fig. 601*)—left phrenic, left vagus, and a branch from the vagus and the sympathetic to the superficial cardiac plexus—and by the left superior intercostal vein. This vein bears the same relationship to these nerves as the azygos arch and the end of the s. v. cava bear to the corresponding right nerves. Its right-posterior aspect curves past the "unit" of four parallel structures (trachea, oesophagus, recurrent nerve, and thoracic duct) and the nerves to the

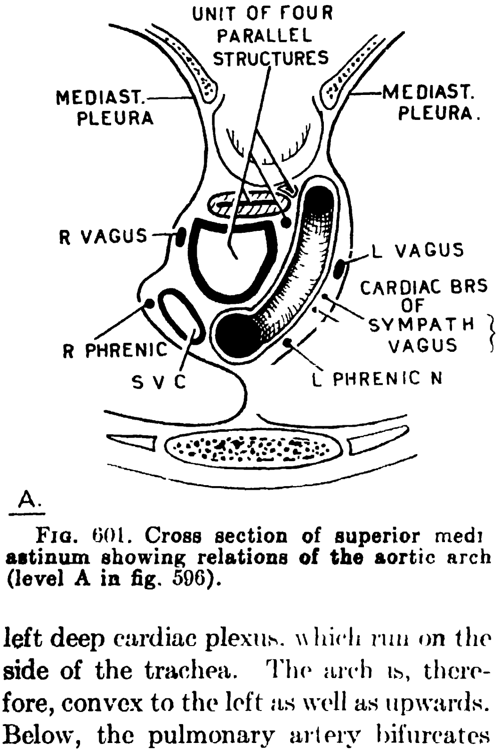


FIG. 601. Cross section of superior mediastinum showing relations of the aortic arch (level A in fig. 596).

left deep cardiac plexus, which run on the side of the trachea. The arch is, therefore, convex to the left as well as upwards. Below, the pulmonary artery bifurcates into right and left branches. The ligamentum arteriosum joins the left pulmonary artery to the concavity of the arch beyond the origin of the left subclavian artery. On the left of the ligament is the left recurrent nerve; on the right is the superficial cardiac plexus.

The left recurrent nerve, therefore, arises on the left, passes below, and ascends on the right of the aortic arch.

The branches of the vagus and sympathetic to the superficial and left deep cardiac plexuses cross respectively on the left and right sides of the arch and the plexuses are united below the arch. Above, its three branches arise, and in front of their stems lies the left innominate vein.

Branches. The first two branches of the aorta are the right and left coronary aa. Hence, the three great vessels arising from the arch are the 3rd, 4th, and

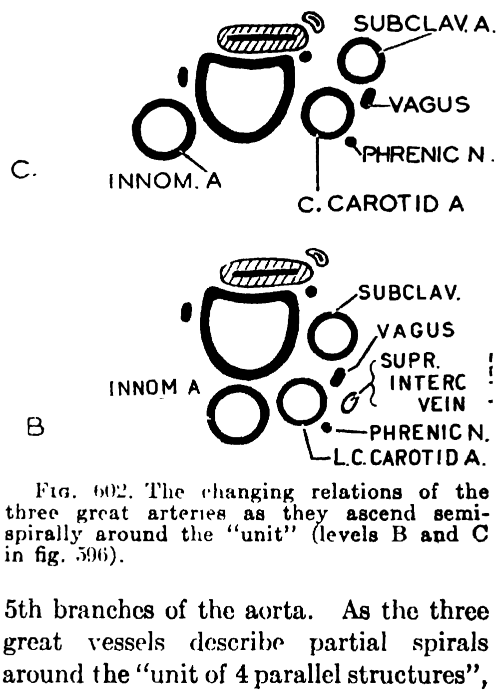


FIG. 602. The changing relations of the three great arteries as they ascend semispirally around the "unit" (levels B and C in fig. 596).

5th branches of the aorta. As the three great vessels describe partial spirals around the "unit of 4 parallel structures", they necessarily have different relationships at different levels; these the diagrams explain more briefly than words can (*fig. 602*). They were described in part with the mediastinal pleura and trachea. Note their relations to: the manubrium and sterno-clavicular joints, the pleurae and lungs, the great veins, the vagus and phrenic nerves.

The *innominate artery* arises at the center of the manubrium and ends by dividing into right common carotid and

subclavian arteries behind the right sterno-clavicular joint. The *left common carotid artery* arises just to the left of the innominate artery, but the *left subclavian artery* arises some distance behind the left carotid. These two vessels pass behind the left sterno-clavicular joint.

On each side, two strap muscles (Sterno-hyoid and Sterno-thyroid) intervene between the arteries and the joint, and the origin of the corresponding innominate vein overlaps them from the lateral side.

Anomalies of the Aortic Arch. (1) Rarely both the right and the left arch persist as in amphibia. They form an arterial ring through which the oesophagus and trachea pass. (2) Rarely the right arch persists and the hinder part of the left arch disappears as in birds, thus reversing the human scheme, with corresponding reversal of the courses of the recurrent nerves. (3) Sometimes (about 1%) the hinder part of the right arch persists as the right subclavian artery and the anterior part disappears. The right subclavian artery then arises as the fourth branch of the aortic arch and passes behind the oesophagus and trachea. The right recurrent nerve is not dragged down but, like the superior laryngeal nerve, descends behind the carotid arteries to the larynx. (4) Occasionally the aortic arch is constricted beyond the origin of the left subclavian artery - perhaps because this portion of the arch was in process of disappearing in expectation that the right arch would persist, as in the bird. In consequence, a collateral circulation has to be established between branches of the subclavian arteries above and the aortic intercostals and inferior epigastric arteries below. They become very tortuous. The condition is known as *co-arctation of the aorta*. (5) Commonly the left common carotid artery arises from the stem of the innominate artery, as is usual in many primates. (6) Commonly the left vertebral artery arises from the aortic arch. (7) The ductus arteriosus may remain patent, generally in combination with other cardiac anomalies.

The Vagus and Phrenic Nerves. Each *Vagus Nerve* descends through the neck, applied to the postero-lateral side of the great carotid stem. Continuing into the thorax, it passes behind the sterno-clavicular joint and the innominate vein (*fig. 603*). The *right vagus* must cross the origin of the right subclavian artery (in front) and the innominate artery (laterally and behind) in order to reach the trachea, which conducts it subpleurally to the back of the root of the right lung. Above the root, the azygos arch crosses it. The *left vagus* continues to descend along the postero-lateral side of the left carotid stem, and therefore in the angle between it and the left subclavian artery, to the aortic arch which it crosses far back in order to reach the back of the root of the left lung.

Branches of the Vagi. In the superior mediastinum, each vagus is responsible for recurrent, cardiac, tracheal, and oesophageal branches. The right recurrent nerve gives off a cardiac branch as it hooks round the right subclavian artery; the other right branches including one cardiac branch spring directly from the right vagus. All the left branches spring from the left recurrent nerve. In the posterior mediastinum, each vagus breaks up to form a posterior pulmonary plexus, reunites, and breaks up again to form the oesophageal plexus, which surrounds the oesophagus. From this oesophageal plexus an anterior (left) and a posterior (right) stem, composed of fibers from both vagi, pass through the diaphragm, one in front of the oesophagus,

the other behind it. Here are given off pleural and pericardial twigs.

Each *Phrenic Nerve* enters the thorax between the subclavian artery and vein, and lateral to the vagus; lateral, in fact, to the thyro-cervical trunk which separates it from the vagus. The *right phrenic* follows subpleurally along the side of the great vertical venous channel (through which a stick was passed) (*fig. 538*). The *left phrenic* nerve, in its strictly subpleural course, passes half-an-inch or more, in front of the root of the lung, and is the most anterior of the four nerves that cross the aortic arch (*fig. 544*). To attain this position it is necessary for it to cross the path of the vagus, which descends behind the root of the lung. The crossing takes place subpleurally half-an-inch in front of the vagus between the origin of the thyro-cervical trunk and the left common carotid artery along whose anterior border the phrenic nerve descends to the aortic arch.

Branches of the Phrenic Nerves. Each phrenic nerve is the sole motor nerve of its own half of the diaphragm, via branches which mostly pierce the diaphragm and spread out subperitoneally. It furnishes sensory fibres to the pericardium and mediastinal pleura and to the central parts of the diaphragmatic pleura and peritoneum. The peripheral parts of the diaphragmatic pleura and peritoneum are supplied by the lower intercostal nerves. Through connections with the diaphragmatic plexus on the inferior phrenic artery; branches reach

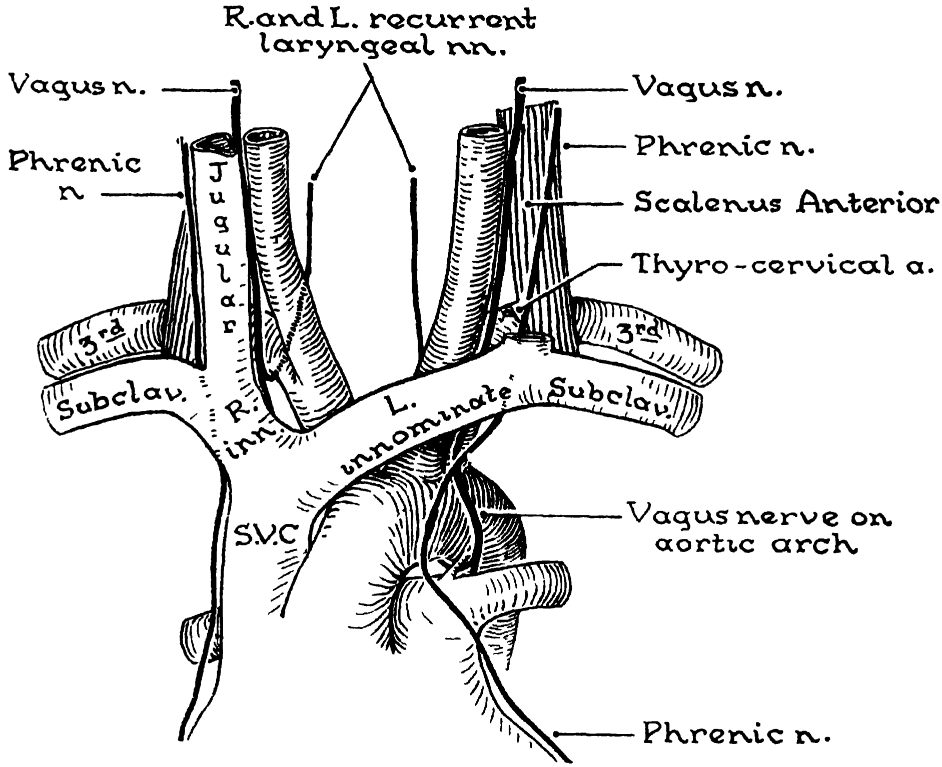


FIG. 603. The courses of the phrenic and vagus nerves.

the adrenal glands and, on the right side, the i. v. cava and the hepatic plexus.

The nerves may profitably be sketched in figure 563.

THE POSTERIOR MEDIASTINUM

The Posterior Mediastinum is a passage or thoroughfare between the superior mediastinum above and the abdominal cavity below (*fig. 604*). It is bounded behind by the bodies of the lower eight thoracic vertebrae, the interposed fibrocartilaginous discs, and the portion of the anterior longitudinal ligament uniting them. In front are the pericardium and the diaphragm. On its right and left sides are the mediastinal layers of pleura. When these layers are traced dorsally, they are seen to pass from the sides of the vertebral column on to the ribs and intercostal spaces as the costal layers of pleura.

Contents.

A. Longitudinal tubular structures:
1. Descending aorta.
2. Thoracic duct.
3. Azygos and hemiazygos veins.
4. Oesophagus (with vagus nerves).

B. Transverse tubular structures:
1. Aortic intercostal arteries.
2. Thoracic duct (from right to left).
3. Certain posterior intercostal veins.
4. Left hemiazygos veins (cross channels).

The sympathetic trunks and the intercostal nerves are covered with costal pleura and therefore are wide of this region.

Postulate. The transversely running structures cling to the thoracic wall; they supply the wall and, like the ribs, are to be regarded as part of the wall (*fig. 605*). The longitudinally running structures are contents of the thorax and lie within its walls. Expressed more briefly: transverse structures lie external to longitudinal structures (*fig. 605*).

In embryonic life, three pairs of symmetrically placed vessels ran side by side through the entire length of the posterior mediastinum (*fig. 606*). There were two arteries, two lymph trunks, and two chains of veins. The two arteries were medianly placed and, so, fused—as medianly placed vessels commonly do[4]—to form the descending thoracic aorta. Out of the laterally placed chains of veins, the (right) azygos and the (left) hemiazygos

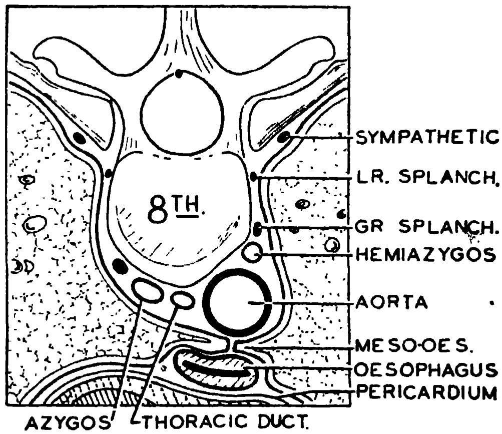


FIG. 604. The posterior mediastinum (in transverse section).

veins took form. The right intermediately placed vessel became the posterior mediastinal portion of the thoracic duct; its left counterpart is rarely if ever present in man.

The Descending Thoracic Aorta is the continuation of the (*left*) aortic arch; so, naturally it runs the first part of its course rather on the left side of the bodies of the upper posterior mediastinal vertebrae (5, 6, and 7) which it commonly grooves or erodes. The descending thoracic aorta, the abdominal aorta, and

[4] Examples are the: Descending aorta, median sacral artery, basilar artery, median arteries of the spinal medulla; sagittal venous sinuses, dorsal vein of the penis.

the caudal aorta (median sacral artery) form a continuous arterial trunk, the result of the fusion of the two paired vessels, known as the right and left primitive dorsal aortae.

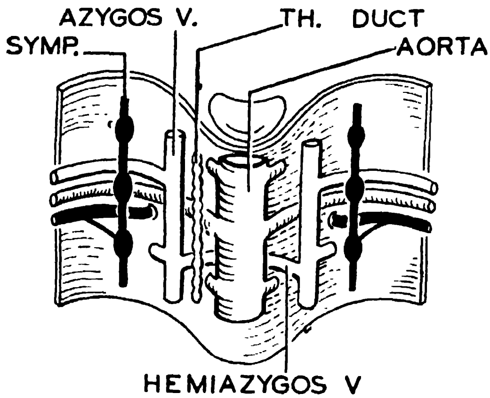


FIG. 605. Postulate: Horizontal structures in the posterior mediastinum belong to the thoracic wall and pass external to longitudinal structures.

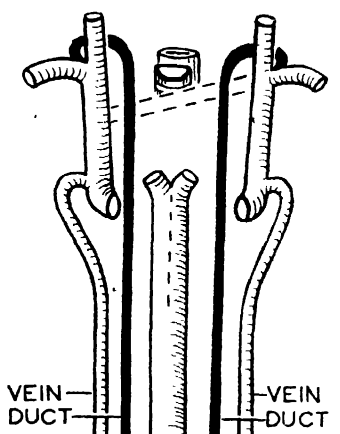


FIG. 606. Three symmetrically placed embryonic vessels.

Behind this trunk lies the vertebral column. Incongruous it may seem, but it is the case that this arterial trunk beats against the vertebral column throughout the whole length of the posterior mediastinum, abdomen, and pelvis without the intervention of any soft padding of fat or muscle to mitigate its ceaseless and incessant shocks. Crossing it posteriorly in the thorax are the slender stems of the left hemiazygos veins; in the abdomen the left lumbar veins (3rd and 4th); in the pelvis not even a vein intervenes.

Throughout the course of the descending thoracic aorta, the thoracic duct and the azygos vein lie on its right postero-lateral side, and accompany it through the aortic orifice in the diaphragm at vertebral level Th. 12——L. 1. The hemiazygos veins lie on its left postero-lateral side, and the left lung curves behind its upper part.

On the left are the mediastinal pleura and lung. *On its right* are the oesophagus in its upper part; the right mediastinal pleura and lung in its lower part. *In front* are: (a) the root of the left lung including the bronchus, pulmonary artery, pulmonary veins, and posterior pulmonary plexus; (b) the pericardium, which separates it from the oblique pericardial sinus and left atrium; (c) the oesophagus, which was to its right opposite 5, 6, and 7 vertebrae, is in front and passing to the left side opposite 8, 9, and 10 vertebrae; (d) the diaphragm at the level of the 11 and 12 vertebrae separates it from the upper recess of the lesser sac of peritoneum and from the caudate lobe of the liver.

Its branches are (a) *visceral:* bronchial (*p. 531*) and twigs to the oesophagus, pericardium, and diaphragm; (b) *parietal:* lower nine pairs of posterior intercostal and one pair of subcostal arteries.

The Thoracic Duct. The primitive lymph ducts (*fig. 606*) were phylogenetically paired right and left vessels[5] that ascended through the posterior mediastinum on each side of the descending thoracic aorta, and through the superior

[5] As in the frog and bird.

mediastinum on each side of the oesophagus till, reaching the root of the neck, each arched laterally immediately behind the carotid sheath (containing the common carotid artery, vagus nerve, and internal jugular vein) to open into the angle between the subclavian and the internal jugular vein. Of the various prevertebral cross-communications between these right and left vessels, one lying on the plane between the posterior and superior mediastina, and therefore not subject to pressure by the aorta, enlarged (*fig. 607*). Thereafter, the flow of lymph is upwards (a) through the posterior mediastinum in the right vessel, (b) across the median plane in the cross-communication, and (c) onwards through the superior mediastinum in the left vessel. This devious channel is known in adult anatomy as the thoracic duct. The diagonally opposite segments of the primitive lymph ducts severed connection with the thoracic duct. The lower left portion disappears (if indeed it ever existed in the human embryo) and the left intercostal lymph vessels mostly follow the example of the left hemiazygos veins in crossing the median plane behind the aorta (according to postulate) and end in the thoracic duct (*fig. 607*).

The thoracic duct begins as the effluent from the cisterna chyli, enters the thorax through the aortic opening in the diaphragm, crosses the twelve thoracic and last cervical vertebrae and then curves laterally in the neck (*p. 671*) to end in the left jugulo-subclavian angle.

The relationship of the thoracic duct to the vertebral column; to the aorta and azygos vein; to the right aortic intercostal arteries and hemiazygos veins; to the oesophagus; to the right and left mediastinal pleurae; and finally to the aortic arch, left subclavian, and left common carotid arteries need no elaboration here.

Communications. If the thoracic duct be cut deliberately or by accident, chyle (the product of the digestion of fat) escapes from the cut end. The fact that evil results rarely follow, provided the duct is tied, indicates that accessory lymphatico-venous communications must exist. The presence of numerous valves makes it difficult to determine by injection their sites in man. It is known that in the New World monkeys the lymph vessels of the digestive organs and of the posterior extremities end in the venous

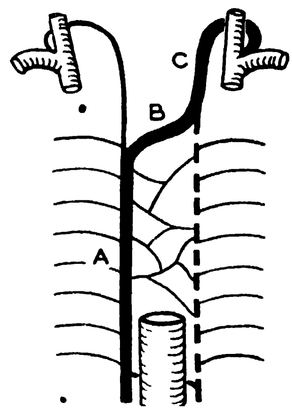


Fig. 607. The thoracic duct.

system near the renal veins and do not join the thoracic duct; that in rats the lymph trunks communicate with numerous veins including the renal, iliolumbar, portal, iliac, jugular, azygos, and vertebral; and that in cats there are communications with the azygos and intercostal veins. Man evidently possesses similar connections.

Variations: Most of the variations possible from diagram 607 have been observed.

The (Right) Azygos Vein and (left) Hemiazygos Veins are variable in their connections and only to be understood when their developmental history is considered. They develop from symmetrically paired right and left chains of

posterior cardinal veins (*fig. 579*). Below, each joined the abdominal chain through the crus of the diaphragm, or behind the medial arcuate ligament, or, in the case of the right vein, through the aortic opening. Each ascended lateral to the respective primitive lymph duct, arched over the root of the lung, where it was joined by the anterior cardinal vein (draining the head, neck, and upper limb) to form the respective common cardinal vein (duct of Cuvier), which opened into the sinus venarum of the primitive heart. The right common cardinal vein became the end portion of the (right) s. v. cava; but the left one atrophied. How then is the blood from: (1) the left intercostal spaces, from (2) the left side of the head and neck and (3) from the left upper limb returned to the heart? By new cross-communications.

A variable number of prevertebral cross-connections, two or more, join the left to the right posterior cardinal chain, (i.e., in terms of adult anatomy connect the upper and lower *hemiazygos veins* to the azygos vein); and, according to postulate, these connections pass behind the aorta and thoracic duct. In the superior mediastinum a large retrosternal cross-connection, the *left innominate vein*, joins the left to the right anterior cardinal vein. The portion of the left anterior cardinal vein just caudal to this "new" left innominate vein remains in order to convey, though now in a reversed direction, blood from the left 2nd, 3rd, and 4th intercostal spaces. This, the *left superior intercostal vein*, crosses the aortic arch between the vagus nerve medially and phrenic nerve laterally to end in the left innominate. The *right superior intercostal vein* (2nd, 3rd, and 4th spaces) ends in the azygos vein. *The 1st posterior intercostal vein* on each side ends in the corresponding innominate vein; the *5th and subsequent veins* end in the azygos or hemiazygos veins (*fig. 579*).

Ultimately, then, all venous blood above the diaphragm, that from the lungs and heart obviously excepted, returns to the heart via the (right) s. v. cava; and all venous blood below the diaphragm, including the portal blood, returns to the heart by the (right) i. v. cava. As in the thorax so in the abdomen, cross-communications (left common iliac vein, left renal vein, and several lumbar veins) transfer blood from the left side of the body to the right side.

The Intercostal and Subcostal Vessels. The upper six pairs of anterior intercostal vessels (arteries, veins, and lymphatics) are branches of the *internal mammary vessels;* the succeeding three pairs spring from its *musculo-phrenic branches*. The short 10th and 11th intercostal spaces are open anteriorly and do not receive anterior intercostal vessels.

The upper two pairs of posterior intercostal arteries, called the *superior intercostal arteries*, are derived from the subclavian arteries via the costo-cervical trunks. Having crossed the neck of the 1st rib, between the sympathetic trunk medially and the branch of the 1st thoracic nerve to the brachial plexus laterally, each supplies the 1st space, crosses the 2nd rib, and supplies the 2nd space.

The remaining nine pairs of posterior intercostal arteries spring from the back of the descending aorta. Those to the 3rd and 4th spaces have necessarily a considerable ascent to make in order to reach their respective spaces.

The subcostal artery with its vein and nerve leaves the thorax behind the lateral arcuate ligament and runs in front of the Quadratus Lumborum. It is in series with the aortic intercostal and lumbar arteries.

Figure 605 schematically depicts the intercostal arteries leaving the aorta in the middle line; the intercostal veins passing to azygos and hemiazygos veins near the middle line; and the intercostal nerves entering the thorax by crossing the upper borders of the necks of the ribs numerically below them and, therefore, wide of the vertebral bodies.

These transversely running vessels and nerves cling to the thoracic wall which they supply and of which they are a part, no structure intervening. The ends of the left hemiazygos veins and the cross-channel of the thoracic duct likewise cling to the wall.

The Oesophagus extends from the pharynx to the stomach, and has, therefore, cervical, thoracic, and abdominal portions. Like the trachea it begins at the lower border of the cricoid cartilage, at the level of the 6th cervical vertebra, and at a distance of 6 inches from the incisor teeth. It pierces the diaphragm behind the seventh left costal cartilage, an inch from the median plane, at the level of the 10th thoracic vertebra, and ends in the stomach less than an inch beyond. It is 10 inches long (*fig. 608*). It is constricted at its origin, at the aortic arch, at the tracheal bifurcation, and where it passes through the diaphragm. At its origin and in the mid-thoracic region it occupies the median plane, elsewhere it is slightly on the left. It is, therefore, not only convex in conformation with the vertebral curvature, but also convex to the right.

When considering *its thoracic relationships* have special regard to: (a) the mediastinal pleurae and lungs, (b) the heart and great arteries, (c) the respiratory tract, (d) the vertebral column, and (e) the thoracic duct. Ask yourself "Where could a sharp foreign body piercing its walls puncture these structures?"

Its right margin is in contact throughout with right mediastinal pleura and lung, save only where the arch of the azygos vein interposes itself, as it arches over the root of the lung.

Its left margin is separated throughout from left mediastinal pleura and lung,

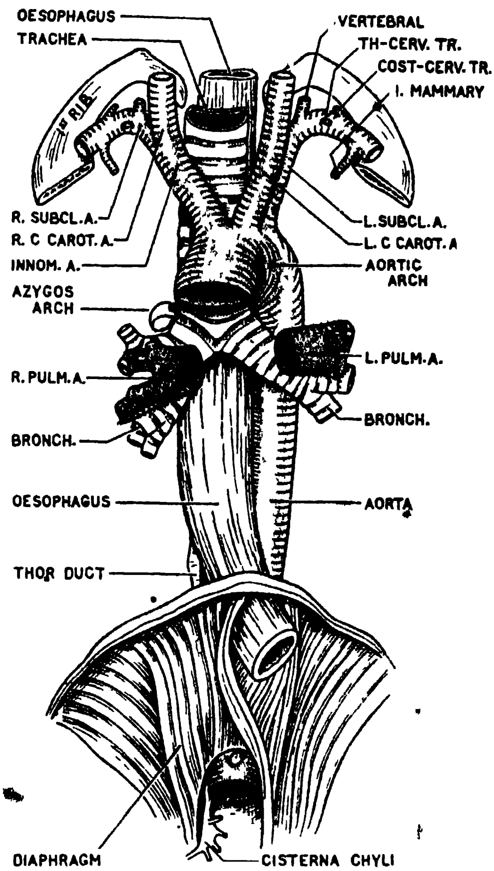


FIG 608. The oesophagus, the aorta and the three branches of the aortic arch.

save at two small areas, by the following 4 arteries: the left common carotid, the left subclavian, the arch of the aorta (where it arches over the root of the left lung at the level of the 4th vertebra), and the descending aorta at the level of the 5th, 6th, and 7th vertebrae. Of the two areas in contact with pleura (a) one is at the level of the 8th, 9th, and 10th verte-

brae where the oesophagus is "suspended" from the front of the aorta by a meso-oesophagus which allows it to curve forwards and to pierce the diaphragm. Here the oesophagus is in contact with both right and left pleurae and lungs behind the pulmonary ligaments. (b) The other area is in the angle between the aortic arch and the left subclavian artery, and here the thoracic duct is applied to its side.

Its posterior surface is related to the upper ten thoracic vertebrae thus: with vertebral bodies 1–4 it is in practically direct contact as only the anterior longitudinal ligament and lower ends of the Longi Cervicis separate it. Intervening at the junction of the superior and posterior mediastina is the cross-channel of the thoracic duct. Intervening at the level of vertebrae 5, 6, and 7 are the thoracic duct, azygos vein, some right intercostal arteries, and (about this level) the cross-channels of the hemiazygos veins. At the level of vertebrae 8, 9, and 10, the descending aorta is gradually interposed. Finally, the oesophagus is well to the left of the median plane with left lung behind it, and here it possesses a meso-esophagus.

Its anterior relations are as follows: the trachea and left recurrent nerve, with the left common carotid and subclavian arteries and the aortic arch crossing the projecting left margin in the superior mediastinum; the bifurcation of the trachea, the bronchi (especially the left), and the inferior tracheo-bronchial glands, all crossed ventrally by the right pulmonary artery, in front of vertebra 5; the fibrous pericardium and oblique pericardial sinus, which alone separates it from the left atrium as far as vertebra 8; lastly, at the level of the vertebrae 9 and 10 is the diaphragm.

VESSELS AND NERVES. Its *arteries* come from the inferior thyroid artery in the neck; the superior intercostal and bronchial arteries and the aorta in the thorax; and the left gastric and inferior phrenic arteries in the abdomen.

Its veins drain to the inferior thyroid, azygos, and left gastric veins. Anastomoses between the last two unite the portal and systemic systems (see oesophageal piles, p. 252).

Its nerves: The recurrent nerves and sympathetic trunk in the neck; the right vagus and left recurrent nerve in the superior mediastinum. Below the bronchi the vagi, joined by branches from the sympathetic and splanchnic nerves, form the oesophageal plexus around the oesophagus. From this plexus two mixed vagus nerves, called the *anterior* and *posterior gastric nerves*, descend on the oesophagus to the stomach. Their positions—in front of and behind the oesophagus, rather than on its sides—are to be attributed to the rotation that the stomach and lower end of the oesophagus have undergone.

SPHINCTERS. There is a sphincter at each end of the oesophagus. At the *gastric or cardiac end* the sphincter is a physiological one, supplied (a) by the vagus which conducts opening impulses (inhibits), and (b) by the sympathetic which conducts closing impulses (contracts). The sympathetic fibers partly ascend from the celiac plexus with the left gastric artery; and partly descend in the thorax from the periaortic plexus. (White and Smithwick.) At the *pharyngeal end* is the Crico-pharyngeus (*p. 722*).

SECTION VII

THE HEAD AND NECK

CHAPTER 19

THE FRONT OF THE SKULL AND THE FACE

The face will be considered under the following headings:

1. The skull viewed from the front.
2. The muscles associated with the oral, nasal, aural, and orbital orifices. The structure of the lips, external nose, auricle, and eyelid.
3. The nerves and vessels of the face.

The Anterior Aspect of the Skull (Norma Frontalis). *Warning:* When handling a skull keep your fingers out of the orbital cavities or you will certainly break their medial walls which are papery in thinness. *Orientation:* At a convention of anthropologists held in Frankfort (1882) it was agreed to examine skulls when so placed that the lower margins of the orbital apertures and the upper margins of the external auditory orifices lie on a horizontal plane— *The Frankfort Plane.* This is roughly achieved by placing a 2″ block under the foramen magnum leaving the point of the chin resting on the table.

CONTOUR OR OUTLINE OF THE NORMA FRONTALIS (*fig. 609*). The vertical height of a skull so orientated and measured from the highest point in the median sagittal plane (vertex) to the level of the point of the chin (progonion) is approximately 200 mm. or 8 inches. The *zygomatic arches* lie at the widest parts of the face and are approximately 5 inches apart. Above them the outline of the skull is rounded because it is formed by the *cranium* or brain case, and it bulges a few millimeters beyond the zygomatic arches. The arches, therefore, are not readily visible when the skull is viewed from above. Below the zygomatic arches the skull is angular and is outlined by the *posterior border of the ramus*, the *angle* (gonion) and the *base* of the mandible.

At birth (*fig. 610*) a median sagittal sutureline bisects the norma frontalis and separates the *parietal*, *frontal*, *nasal*, *maxillary*, and *mandibular* bones of the two sides. The two sides of the mandible fuse at the *symphysis menti* during the second year, but in most mammals they remain separate throughout life. The two sides of the frontal bone fuse about the sixth year, but in some skulls (8 per cent) they remain separate; that is, the interfrontal or *metopic suture* persists; and in other skulls the lower end of this suture remains. The interparietal or *sagittal suture* is usually obliterated by the age of 35 years. The nasal bones fuse occasionally; the maxillae almost never.

The *bregma* is the point at which the sagittal and coronal (fronto-parietal) sutures intersect. It is situated one inch in front of the vertex or highest point.

The medial margins of the somewhat quadrangular *orbital apertures* are fully one inch apart; their lateral margins are four inches apart; hence, the transverse diameter of each aperture is one and a half inches. The vertical diameter is slightly less than the transverse. Each of three bones—frontal, maxillary, and zygomatic—forms approximately one-

third of the orbital margin. The frontal bone descends lower medially, where it articulates with the *lacrimal bone* and *frontal process of the maxilla*, than lat- of sex. The elevation between the superciliary arches, and therefore between the eyebrows, is called the *glabella* because the overlying skin is bald or glabrous.

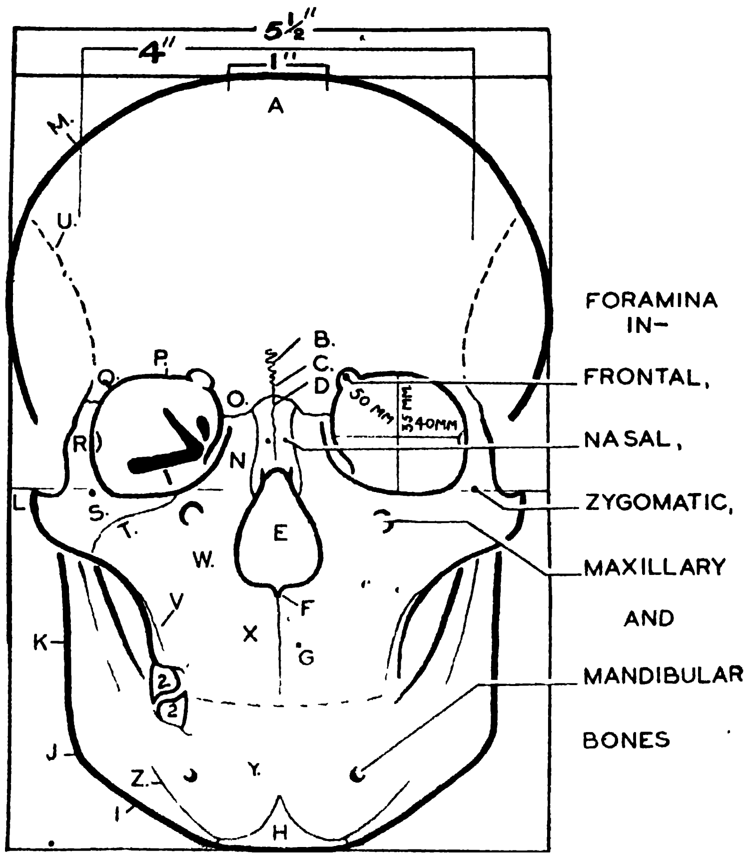


FIG. 609. The norma frontalis. *Median plane:* (A) Bregma; (B) Metopic suture (remains); (C) Glabella; (D) Nasion; (E) Piriform aperture; (F) Antr. nasal spine; (G) Intermaxillary s.; (H) Mental protuberance.
Contour: (I) Base of jaw; (J) Angle of jaw; (K) P. border of ramus; (L) Zygomatic process; (M) Cranial outline.
Orbital margin: (N) Front pr. maxilla; (O) Max. pr. frontal; (P) Superciliary arch; (Q) Zyg. proc. front; (R) Front pr. zygomatic; (S) Max. pr. zygomatic; (T) Zyg. pr. of maxilla.
Other features: (U) Temporal line; (V) Buttress; (W) Canine fossa; (X) Incisive fossa; (Y) Incisor fossa; (Z) Ext. oblique line.

erally where its *zygomatic process* articulates with the *frontal* (fronto-sphenoidal) *process of the zygomatic bone.* The fullness above the medial part of the supraorbital margin of the frontal bone is the *superciliary arch.* The arches are well marked in the male and are a criterion

The *anterior nasal* or *piriform aperture* lies below and between the orbital apertures. Its sharp, pear-shaped margin is formed by the nasal bones above; by the maxillae laterally and below. A median spine of bone, the *anterior nasal spine,* juts forwards from the maxillae and helps

to support the septal cartilage of the nose. The *nasion* is the point at the root of the nose where the fronto-nasal suture crosses the median sagittal plane. It lies in a deep depression.

The upper border of the *zygomatic arch*, when traced forwards, bends upwards and medially lateral to the orbit and then, as the *temporal line*, it curves backwards across the side of the cranium to reach a point about *midway* between the zygomatic arch and the vertex. The temporal line separates the *temporal fossa* below from the *region of the scalp* above. If the temporal muscles are powerful and therefore large, and if the brain and therefore the brain case are small, then the temporal lines of the two sides approach each other more closely. In some dogs and apes they meet in the median plane and rise, like the crest on a Roman helmet, in order to afford increased origin for the temporal muscles.

The lower border of the zygomatic arch, when traced forwards, curves downwards and medially and becomes continuous with the lower border of the *zygomatic process* of the maxilla, which in turn becomes continuous with a ridge that descends to the second molar tooth. This ridge or buttress separates the *facial surface* of the maxilla from the *infratemporal surface*.

There are 32 *teeth* in all, sixteen in each jaw. Of the 8 upper and lower teeth on each side, two are *incisors* or cutting teeth, one is a *canine* or tooth such as dogs have, two are premolar or *bicuspid* teeth for their crowns have two cusps, and three are *molar* or millstone teeth. The roots of the teeth are embedded in little troughs or alveoli contained in the *alveolar processes* of the maxilla and mandible. The 16 teeth forming the upper *dental arcade* overlap the 16 teeth of the lower dental arcade; hence, the crowns of the lower teeth are worn and rounded on their outer or *labial edges;* the upper teeth on their inner or *lingual edges.*

Man alone has a *chin* and an *anterior nasal spine.* Their presence is attributed to the fact that he does with his hands what other animals do with their mouths, e.g., carries, attacks, and defends. Relieved of these duties, the teeth and alveolar processes of the jaws recede, leaving the chin and anterior nasal spine as projections (*fig. 611*).

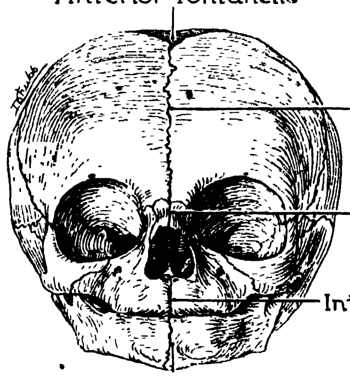


FIG. 610. The skull at birth, front view. (For side view see fig. 796, p. 804.)

The skull has but one pair of moveable joints, the *temporo-mandibular* or *jaw joints.* Here a bone of the face articulates with a bone of the cranium. When the teeth of the lower jaw close on the upper teeth a force ranging from 150 to 300 pounds can be exerted. Therefore, to prevent the mandible, which is the strongest bone of the face, from crushing the hollow maxilla and compressing it beneath the cranium, a buttress or strengthening bar is provided in the form of a ridge that extends from the (first or) second molar tooth to the zygomatic bone. This ridge and the zygomatic process of the maxilla transmit to the

zygomatic bone the upward thrust imparted by the molar (and premolar) teeth. This it largely disperses to the cranium (a) via its frontal (fronto-sphenoidal) process along the lateral side of the orbital margin, and (b) via its temporal process to the temporal bone. Stresses from the front teeth are mainly transmitted (c) via the frontal process of the maxilla (upper jaw) along the medial side of the orbital margin.

The sockets for the canine teeth cause ridges on the upper and lower jaws. The area on each jaw medial to the canine ridge, and therefore overlying the roots of the incisor teeth, is the *incisive fossa*. The area on the upper jaw between the canine ridge and the zygomatic process and the ridge descending from it to the second molar tooth is the *canine fossa*.

At the point of the chin, there is a slightly raised triangular area, the *mental protuberance*. From its lateral angle an *oblique line* runs upwards and backwards to become continuous with the *anterior border of the ramus* of the jaw.

Foramina. Three intra-osseous foramina open on to the face on a vertical line that passes between the bicuspid teeth. They penetrate the frontal, maxillary, and mandibular bones about $1\frac{1}{4}$ inches from the median plane and transmit sensory branches of the first, second, and third divisions respectively of the trigeminal nerve and their companion vessels. They are named the *supra-orbital, infra-orbital,* and *mental* foramina. The mouths of the foramina point in the direction taken by the emerging nerves and vessels.

During fetal life the supra-orbital and infra-orbital nerves and vessels run along the roof and floor respectively of the orbital cavity; the former turning round the upper margin of the orbital aperture on to the forehead; and the latter round the lower margin on to the face. Depending on the extent to which the frontal bone later envelops the supra-orbital nerve and vessels, there is a supra-orbital notch—foramen—or canal. A *pinpoint orifice* for the frontal diploic (medullary) vein is visible in the notch. Similarly, a process from the infra-orbital margin of the maxilla grows medially over the infra-orbital vessels and nerve and forms a roof for them. In the hinder part of the floor of the orbital cavity they lie in a gutter; in the anterior part in a canal that opens downwards and medially. At birth the suture line is still apparent. In a similar fashion the

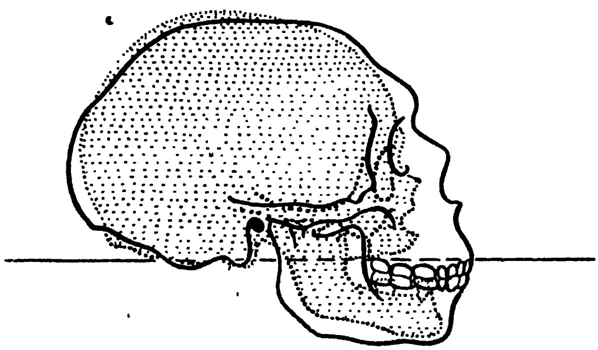


FIG. 611. Superimposed profiles of a modern white skull (stippled) and a prehistoric skull (clear). Note the recession of the face and the appearance of a chin in the modern skull. (After Boule.)

mandible grows round the inferior dental (alveolar) nerve and vessels, thereby forming the mandibular canal. The mental foramen is the anterior orifice of this canal. Because the emerging mental nerve and vessels are mainly directed upwards and laterally to the lower lip, the orifice opens upwards and laterally.

and from it spread over the face, dragging after them branches of the facial nerve, which is the nerve of this arch. The *Platysma*, which spread downwards over the neck, and the *Epicranius*, which spread upwards over the scalp, are derived from the same source and are supplied by the same nerve.

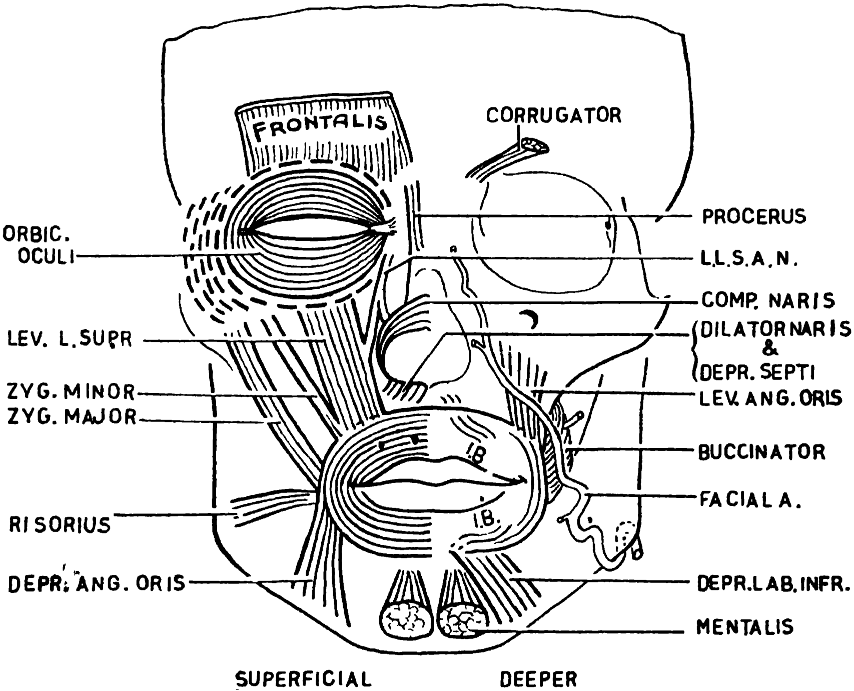


FIG. 612. The muscles of the face.

Two minute intra-osseous foramina pierce the zygomatic and nasal bones and open on to the face: the zygomatic bone is pierced near its center by the zygomatico-facial nerve and a twig of the lacrimal artery; the nasal bone by a vein from the nose.

Muscles of the Face (*fig. 612*). The facial muscles or muscles of expression are disposed around the orifices of the mouth, eye, nose, and ear, as sphincters and dilators. Developmentally, they took origin in the hyoid or 2nd branchial arch

One muscle on the face - the *Masseter* —is not supplied by the facial nerve. It covers the ramus of the jaw and is a muscle of mastication. Like the other muscles of mastication, it developed from the mandibular or 1st branchial arch and like them it is supplied on its deep surface by the third division of the trigeminal nerve (V^3), which is the nerve of this arch.

The Mouth. The *Orbicularis Oris* or sphincter of the mouth extends upwards almost to the nose and downwards

to the transverse groove on the skin midway between the chin and red portion of the lips. Four slips, the *incisive bands*, arise from the incisive fossae of the upper and lower jaws and turn laterally into the Orbicularis. They help to purse and pout the lips.

Converging on the angle of the mouth where they blend with the Orbicularis Oris are 4 muscles—the *Levator Anguli Oris* (Caninus), which arises below the infra-orbital foramen; the *Zygomaticus Major* or smiling muscle, which arises from the bone of the same name: the *Risorius* or grinning muscle, which arises from the parotid fascia; and the *Depressor Anguli Oris* (Triangularis), which arises from the oblique line on the mandible.

Attached to the upper lip are three bands, which arise from the medial and lower borders of the orbital margin. They are called the *Levator Labii Superioris Alaeque Nasi*, *Levator Labii Superioris*, and *Zygomaticus Minor*. [In the B. N. A. terminology they are called the angular, infra-orbital, and zygomatic heads of the Quadratus Labii Superioris.] The first gives a slip to the ala of the nose, the second is broad, quadrate, and arises above the infra-orbital foramen, the third is a mere slip. Attached to the lower lip is the *Depressor (Quadratus) Labii Inferioris*, which arises from the oblique line of the mandible between the mental foramen and the mental protuberance (L. Mentum = the chin). It is rhomboidal. Its medial border meets and decussates with that of its fellow above the transverse groove on the lip and, so, leaves a triangular space above the mental protuberance. This the Mentales occupy.

Each *Mentalis* passes from the lower incisive fossa downwards to be attached to the skin over the chin. It is conical. When it contracts it raises, protrudes, and puckers the skin over the chin and accentuates the transverse fold. To expose its origin, it is necessary merely to evert the lower lip and incise the mucous membrane over the incisive fossa. This exposes also the lower incisive band and the mental nerve.

The *Buccinator* (L. Bucca = the cheek; Buccinator = a trumpeter) is a flat muscle whose inner surface is lined with the mucous membrane of the cheek and lips. Above and below, it arises from the outer surfaces of the alveolar processes of the maxilla and mandible, lateral to the molar teeth. Posteriorly, it is continuous with the Superior Constrictor of the pharynx, the line of union being marked by an indefinite fibrous raphe, the *pterygo-mandibular lig. or raphe* (*fig. 723*), that extends from the hamulus of the medial pterygoid plate to the mandible behind the 3rd molar tooth. Anteriorly, it extends into the upper and lower lips and there blends with the Orbicularis Oris; the upper and lower fibres pass directly into the respective upper and lower lips, but the intermediate fibres decussate behind the angle of the mouth, the upper fibres passing into the lower lip, the lower fibres into the upper lip.

The Buccinator retracts the angle of the mouth and is therefore the antagonist of the Orbicularis Oris. It aids in mastication by pressing the cheeks against the teeth, thereby preventing food from collecting in the vestibule of the mouth. Dogs have no cheeks and cannot chew. It also acts in blowing and in sucking. In order to satisfy yourself of this, pass your left index finger well into the right side of the vestibule and perform chewing, sucking, and blowing movements.

The Buccinator is covered externally with a thin areolar membrane which is

continued posteriorly over the Constrictors of the pharynx; hence, the entire membrane is called the *bucco-pharyngeal fascia*. It is supplied by the buccal branch of nerve VII; it is pierced by the buccal branches of nerve V^3, also by the parotid duct and the ducts of a cluster of small mucous glands, the *molar glands*, that lie on the bucco-pharyngeal fascia near the parotid duct. The space between the Buccinator medially and the ramus of the jaw laterally is occupied by an encapsuled mass of lobulated fat, the *buccal pad* or *sucking pad* of fat

The Lips. If you run the tip of your tongue across the back of your lower or upper lip, you will feel the small nodular mucous and serous *labial glands* that here form an incomplete subepithelial tunic

If you grasp the margin of your upper or lower lip between your finger and thumb, you will feel the pulsations of an *arterial ring* lying between the labial muscles and the tunic of labial glands. It is formed by the *superior* and *inferior labial arteries*.

The lip margins are red partly because the skin is rendered translucent by eleiden and partly because the vascular papillae or thelia are unusually long. Historically, the term "epithelium" was first applied to the cells covering the thelia of the lip.

The External Nose. The framework of the external nose is made of bone, hyaline cartilage, and fibro-fatty tissue. The cartilages (septal, upper nasal, and lower nasal) are remains of the primitive or embryonic cartilaginous nasal capsule; whereas the nasal bones and the fronto-nasal processes of the maxillae developed in the membrane that overlay the cartilaginous capsule. The *septal cartilage* lies in the partition or septum between the right and the left nasal cavities. Its lower free border can be felt by pressing upwards just in front of the anterior nasal spine, but it is best felt by the tips of the index and thumb inserted within the anterior nares or *nostrils*. It will then be appreciated that the tip of the nose and the *columna*, that is, the lower border of the nasal septum, are formed by the medial limbs of the U-shaped lower nasal cartilages (cartilages of the aperture) (*figs. 613, 614*). The large lateral limb of the *lower nasal cartilage* does not extend to the lower part of the ala of the nose, which, like the lobule of the ear, is composed of fibro-areolar tissue. The right and left *upper nasal cartilages* are not entities but are wing-like expansions of the septal cartilage. They are firmly united to the nasal bones above and maxillae behind, but are connected only loosely with the lower cartilages below.

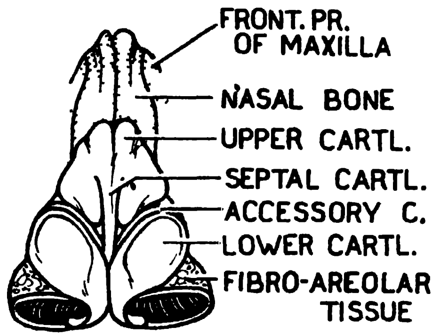


FIG 613. The framework of the external nose (front view)

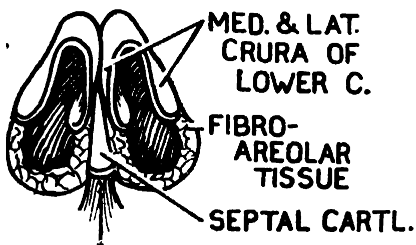


FIG. 614. The framework of the external nose (viewed from below).

On removing the *nasal bones* from a

skull, it is readily appreciated that the nasal notch of the frontal bone receives their upper ends, that the spine of the frontal bone and the septal cartilage support them in the median plane behind, and that the frontal processes of the maxillae support their postero-lateral borders. All these take the impact of a blow on the nose. The opposed surfaces of the nasal bones are flat and triangular, the base being above (*figs. 746, 790*). The posterior surface of each bone is covered with mucous membrane and is grooved by a branch of the internal nasal nerve. The nerve passes between the

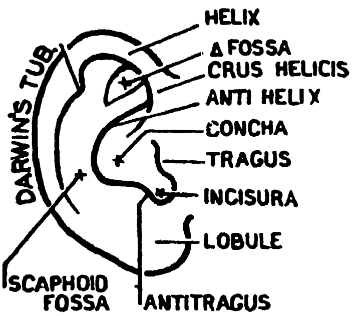


FIG. 615. The auricle.

bone and upper cartilage to the outer surface of the nose and, as the external nasal nerve, continues to the tip of the nose (*fig. 621*).

The lower nasal cartilage is movable; and, when during deep breathing the *Levator Labii Superioris Alaeque Nasi* pulls on its lateral limb, the nostril dilates. The *Compressor Narù.* (Pars Transversa Nasalis) crosses the upper cartilage and, joining its fellow, forms a sling across the bridge of the nose. Large *sebaceous glands* occur near the tip.

The Auricle of the Ear. The framework of the *auricle* is made of a single piece of elastic cartilage except at its most dependent part—the part to which earrings are attached—called the *lobule*, which is made of fibro-areolar tissue. The cartilage is continuous with the cartilage of the external auditory meatus (meatus. L. = a canal) (see p. 767). The shape of the auricle depends on the shape of its cartilage, for here there is no subcutaneous fatty layer. The names of its elevations and depressions are given in figure 615. Of these, note that *Darwin's tubercle* represents the morphological apex. Fine downy hairs and numerous sebaceous glands occur over the auricle; and from the *tragus* and *antitragus* grow hairs that guard the *external meatus*.

Determine on your own auricle that the skin is freely movable on the cranial

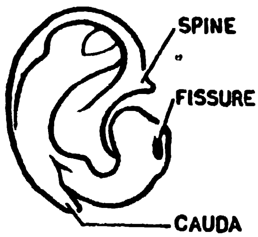


FIG. 616. The cartilage of the auricle.

surface and on the helix, but adherent on the external surface.

Muscles. The auricle has several rudimentary intrinsic muscles and 3 extrinsic muscles Auriculares Posterior, Superior, and Anterior- all supplied by the facial nerve. The Posterior springs from the mastoid bone; the other two from the epicranial aponeurosis. The intrinsic muscles are easily displayed because of the absence of fat.

The Sensory Nerves are the auriculotemporal (V^3), the great auricular (C. 2, 3), and the lesser occipital (C. 2), also two twigs, the *auricular branches of the vagus* and *facial nerves.* The twig from the facial nerve is assumed to exist in order to account for a condition called "auricular zoster".

The Blood Supply comes from the superficial temporal and posterior auricular arteries. Some branches of the latter turn round the helix to reach the lateral surface, while others pierce the cartilage and perichondrium. In a suitable light, they can be seen in the living person.

The Orbital Aperture, the Eyelid, and the Tear Drainage. DEFINITIONS. The upper and lower eyelids or *palpebrae* are united laterally and medially by the corresponding *palpebral commissures.* The opening between the lid margins is the *palpebral fissure.* The lateral and medial angles of the fissure are commonly called the medial and lateral *canthi.* The posterior $\frac{5}{6}$ of the outer coat of the eyeball is white, tough and called the *sclerotic coat;* its anterior $\frac{1}{6}$ is transparent and called the *cornea.* Through the cornea the varied colored *iris* is seen, and in the center of the iris is the *pupil.* The potential space between the eyeball and the eyelid is the *conjunctival sac.* The membrane lining the sac is the *conjunctiva.* At the upper and lower limits of the sac the conjunctiva is reflected from eyeball to eyelid. The reflections are the *fornices* of the conjunctiva.

EXAMINATION. When examining the eye of your partner, or when examining your own eye in a looking glass, observe that: (a) The margin of the lower lid crosses the lower limit of the cornea; the margin of the upper lid crosses the cornea midway between the pupil and the corneal margin; so, no sclerotic is seen either above or below the cornea, but only at its sides (*fig. 617*). On looking upwards—dropping the chin while looking forwards achieves the same result—the sclerotic comes into view below. (b) The lateral $\frac{5}{6}$ of the lid margins are flat, 1 mm. thick, and carry eyelashes or *cilia.* They form the *ciliary parts* of the margins. The medial $\frac{1}{6}$ are devoid of hairs and are rounded, and as the *canaliculi* that drain away the tears traverse them, they may be called the *lacrimal parts* of the lid margins. (c) The entire margin of the upper lid and the ciliary part of the margin of the lower lid form semi-elliptical curves; but the lacrimal part of the lower margin is straight. (d) At the medial canthus there is a triangular area, the *lacus lacrimalis.* It is bounded above and below by the lacrimal parts of the lids and laterally by a free crescentic fold of conjunctiva, the *plica semilunaris.* The plica is very well

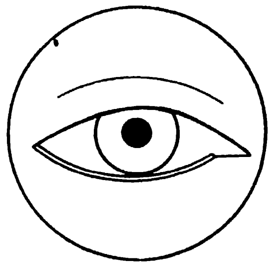


FIG. 617. The margins of the eyelids.

marked in the cow; perhaps it represents the membrana nictitans or third eyelid in the bird. In the lacus there is a reddish area, the *caruncle,* which developmentally is a detached part of the lower lid. It contains some colorless hairs and sebaceous and sweat glands.

Gently pull down and evert the lower lid and note that: (e) At the junction of the ciliary and lacrimal parts of its margin there is a *papilla* on which the *punctum* or entrance to the inferior lacrimal canaliculus can easily be seen. Because its mouth is directed backwards so as to be applied to the eyeball, it is able to suck up tears. The corresponding structures in the upper lid are not so well marked. (f) The conjunctiva is firmly adherent to the back of the lid and to the front of the cornea, but at the fornix and where it covers the sclerotic coat it is

loosely attached and freely moveable and its vessels can be seen to move with it. The lid is so closely applied to the ball of the eye that foreign particles rarely enter the lower part of the conjunctival sac. (g) Yellow streaks, the lines of the *tarsal glands*, are apparent on the back of the lid.

Evert the upper lid over a match stick and note that: (h) The tarsal glands are better marked than in the lower lid. (i) A sulcus lies near and parallel to the

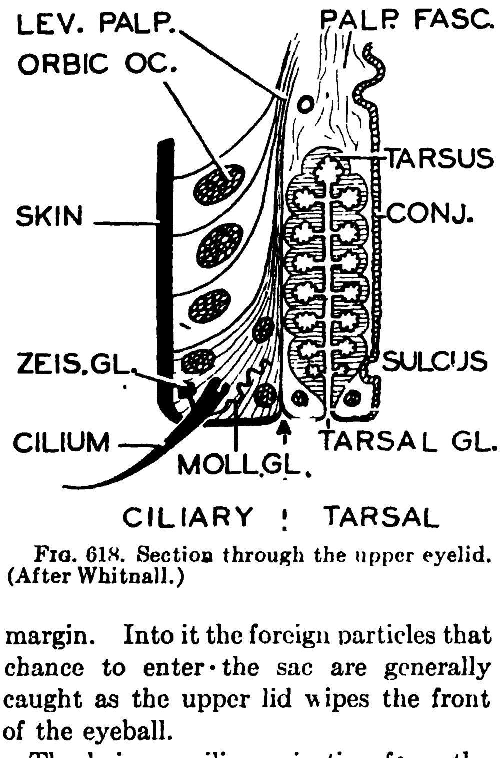


FIG. 618. Section through the upper eyelid. (After Whitnall.)

margin. Into it the foreign particles that chance to enter the sac are generally caught as the upper lid wipes the front of the eyeball.

The hairs or cilia projecting from the lid margins are in two or three irregular rows. Hairs imply the presence of sebaceous glands, and such (as glands of Zeis) open into each hair follicle. Sweat glands (of Moll) likewise open into or beside the hair follicles (*fig. 618*). These glands are situated in front of the tarsal plates. The *tarsal glands* (of Meibomeus), embedded in the back of the tarsal plates, are modified sebaceous glands, visible as yellow streaks through the conjunctiva. On stroking them in the cadaver with the end of the handle of the scalpel, threads of white sebum are expressed on to the lid margin, like paste from a collapsible tube. An obstructed and inflamed hair follicle or stye will project on the front of the lid; an obstructed tarsal gland on to the globe of the eye.

The chief duty of the lids is to keep a film of tears spread over the eyeball, and the upper lid wipes the eyeball free from dust and foreign particles.

THE PALPEBRAL FASCIA, OR SEPTUM ORBITALE. The eyelids develop as folds of skin which come together and adhere along their edges during the middle three months of intra-uterine life (*fig. 519*). At the end of the 6th fetal month, when they become free again, the palpebral fissure is re-established. (In kittens, the lids remain adherent for some days after birth.) During the middle three months the palpebral fascia, which forms the framework or skeleton of the eyelids, may be regarded as forming a complete diaphragm for the orbital cavity, for it is attached to the orbital margin all round, except medially where it passes behind the tear sac to gain attachment to the lacrimal bone, there creating a sharp ridge, the *posterior lacrimal crest* (*fig. 791*). We may speak, then, of two orbital cavities—the cavity behind the bony margin of the orbit and the cavity behind the palpebral fascia. The distinction is a practical one because the tear-sac is within the bony orbital cavity but outside the fascial one; so, it can be operated upon without danger of infecting the "retro-fascial" orbital cavity.

Condensation and thickening of the palpebral fascia take place over an almond-shaped area in the upper lid and

over a rod-shaped area in the lower lid resulting in the formation of the upper and lower *tarsal plates*. These plates are anchored to the orbital margin by the *medial* and *lateral palpebral ligaments*. are firmly closed. Some muscle fibers, the *Pars Lacrimalis* (Tensor Tarsi), are carried medially behind the tear-sac and there find attachment to the posterior lacrimal crest (*fig. 620*). They serve to

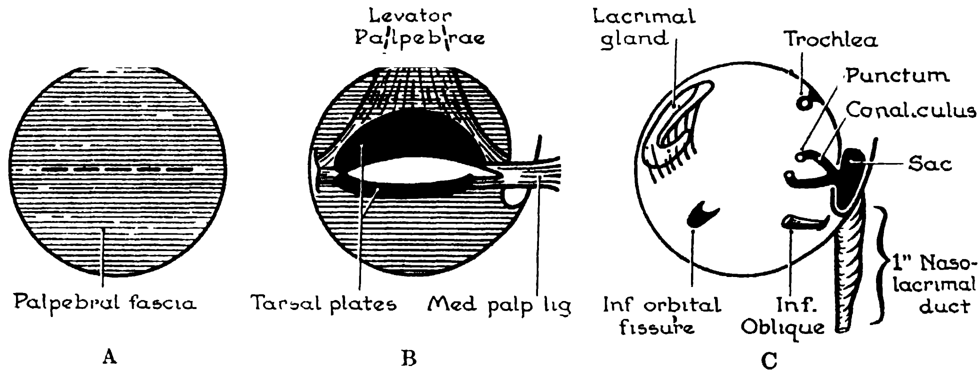


FIG. 619 (A) The palpebral fascia (B) The tarsi, ligaments, and Levator Palpebrae. (C) Features at the four corners of the orbital margin, and the tear apparatus (schematic).

The lateral ligament or raphe is merely a thickening of the palpebral fascia; not so the medial ligament for it passes in front of the tear-sac and is attached to the frontal process of the maxilla.

MUSCLES. The *sphincter* of the palpebral fissure is the *Orbicularis Oculi* The fibers within the lids, the *palpebral portion,* take an arched course from medial to lateral palpebral ligament in front of the palpebral fascia Though striated and supplied by a somatic nerve, they usually act involuntarily, closing the lids in sleep and in blinking. The fibers of the peripheral or *orbital portion* pass in circles from the medial palpebral ligament and adjacent part of the frontal bone across the forehead, temple, and cheek back to the medial ligament and adjacent part of the maxilla. They can also act involuntarily. Having no lateral attachment, they draw the lids medially and thereby encourage tears and particles of dust to the medial canthus. They are responsible for the "crows foot" wrinkles seen at the lateral angles when the eyes

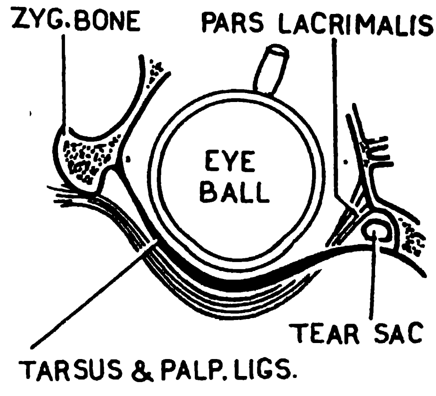


FIG. 620. Horizontal section of globe and upper lid. The upper lid, which moves like a visor and wipes the globe, is kept applied to it by the Pars Lacrimalis (Tensor Tarsi). (After Whitnall.)

keep the lids so closely applied to the eyeballs that foreign particles cannot readily accumulate behind them, and by creating a vacuum in the sac aspirate tears.

The *dilator* of the palpebral fissure is the Levator Palpebrae Superioris. Involuntary muscle fibers in both lids, called the superior and inferior palpebral

(tarsal) muscles, tend to widen the fissure (*fig. 657*).

Two other muscles, the Frontalis and Corrugator Supercilii, are associated with the eye. The *Frontalis* is the muscle that causes the transverse wrinkles on the forehead, associated with a surprised and supercilious look. Raising the eyebrows brings it into play. It arises from the epicranial aponeurosis, which splits to enclose it two or three inches above the brow. Its most medial fibers are prolonged, in contact with those of its fellow, on to the nose as the *Procerus*. The remaining fibers cross the brow and interlock with those of the Orbicularis. The fascia lining the deep surface of the Frontalis (*fig. 624*) is attached to the bone above the supra-orbital margin; it would prevent the downward spread of fluid into the eyelids. The *Corrugator Supercilii* is the muscle that causes the short vertical wrinkles in front of the glabella on frowning, displaying annoyance, and exhibiting pain. It arises from the glabella deep to the Frontalis and as a small band runs laterally deep to the eyebrows and interlocks with the Frontalis and Orbicularis (*fig. 612*).

TEAR DUCTS. The upper and lower *lacrimal canaliculi* are about 10 mm. long. They take a curved course near the free margin of the lid from *lacrimal punctum* to lacrimal sac which they enter either separately or by a common orifice. The *lacrimal sac* is but the upper end of the *naso-lacrimal duct* (*fig. 619, C*). It lies behind the medial palpebral ligament and in front of the Pars Lacrimalis of the Orbicularis Oculi and the palpebral fascia. It is surrounded by veins, and is separated from the atrium of the nose by the papery lacrimal bone and the strong frontal process of the maxilla, and an anterior ethmoidal air cell generally intervenes between its upper half and the atrium.

The *naso-lacrimal duct* continues downwards between lacrimal, maxillary, and inferior conchal bones to open into the inferior meatus of the nose (*fig. 746*).

The Nerve Supply of the Face. SENSORY NERVES OF THE FACE (*fig. 621*). The face is developed from three rudiments, the ***frontal-nasal***, ***maxillary***, and ***mandibular processes***, each of which is supplied by one of the three branches (V^1, V^2, and V^3) of the Vth or trigeminal nerve. These are known as the ophthalmic, maxillary, and mandibular nerves respectively. And, as they are the first, second, and third branches of the trigeminal or fifth cranial nerve they may be indicated by the signs V^1, V^2, and V^3. The great auricular nerve (C. 2 and 3), however, encroaches on the face sending branches across the parotid gland and the Masseter, and deep sensibilities are mediated by the facial nerve.

The Ophthalmic Nerve (V^1). Of the five cutaneous branches of V^1, four are related to the upper lid; one to the nose. The *lacrimal branch* pierces the palpebral fascia in the lateral part of the lid. The *supra-orbital branch* emerges through the supra-orbital notch, foramen, or canal, as the case may be. It then divides into a medial and a lateral branch. These ascend on (and may groove) the frontal bone for about two inches before piercing the Frontalis and passing backwards almost to the lambdoid suture. The *supratrochlear* branch pierces the palpebral fascia above the trochlea for the Superior Oblique and, then pierces the Frontalis to supply the region above the glabella. The *infratrochlear branch* pierces the same fascia and muscle below the trochlea to supply the structures about the medial palpebral commissure, including the lacrimal sac. The 4 pre-

ceding nerves supply also the conjunctiva of the upper lid. The *external nasal branch* emerges at the lower border of the nasal bone, which is easily palpated with the finger nail, and descends on the nasal cartilages to the tip of the nose

Branches derived from the ophthalmic artery accompany these nerves: they are appears through the foramen of that name. It is but a twig. The *zygomatico-temporal* branch appears through the foramen of that name in the temporal fossa, pierces the temporal fascia behind the tubercle on the frontal process of the zygomatic bone, and supplies the anterior part of the temporal region.

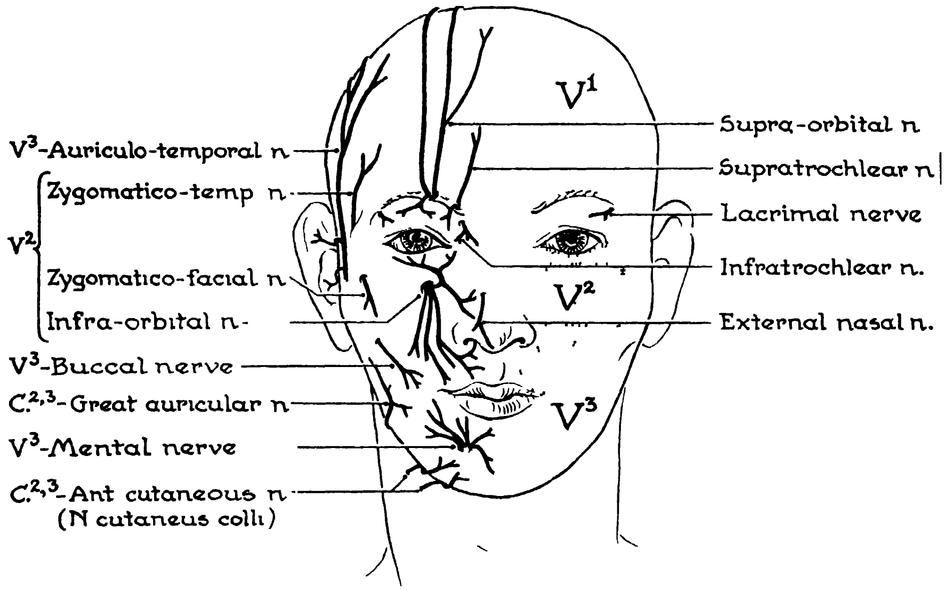


FIG. 621. The sensory nerves of the face and front of the scalp.

the lacrimal, supra-orbital, supra-trochlear, dorsal nasal, and external nasal arteries.

The Maxillary Nerve (V^2). Of the three cutaneous branches of V^2, the *infra-orbital branch* emerges through the infra-orbital foramen. and finds itself between the Levator Labii Superioris and the Levator Anguli Oris. Its branches pass mainly downwards and medially to the upper lip and to the mucous membrane of the cheek and upper gums. It also supplies the skin and conjunctiva of the lower eyelid, and the dorsum of the nose, and it sends branches below the ala of the nose to the skin of the vestibule. The *zygomatico-facial branch* Arteries of the same names accompany these nerves.

The Mandibular Nerve (V^3). Of the three cutaneous branches of the V^3, the *mental branch* emerges through the mental foramen and finds itself deep to the Depressor Anguli Oris Its branches pass mainly upwards to the skin and mucous membrane of the lower lip and gums; others pass to the skin of the chin. The *buccal branch* appears at the anterior border of the Masseter, below the level of the parotid duct. It is easily picked up as it runs almost to the angle of the mouth. It supplies the skin of the cheek, and branches that pierce the Buccinator supply the mucous

membrane of the cheek. The *auriculo-temporal branch* crosses the posterior root of the zygoma just in front of the ear and ascends behind the superficial temporal artery Its name suggests its terminal distribution to auricle and temporal region, but it also supplies the outer surface of the tympanic membrane and external meatus.

the *point of the chin* via the mental n.; (d) from the *tip of the auricle* via the lesser occipital n.; and (e) from the *lobule of the ear* via the great auricular n.

MOTOR SUPPLY TO THE FACE (*fig.* 622). The facial or VIIth cranial nerve is developmentally the nerve of the hyoid arch and it falls to it to supply all the muscles derived from this arch. They

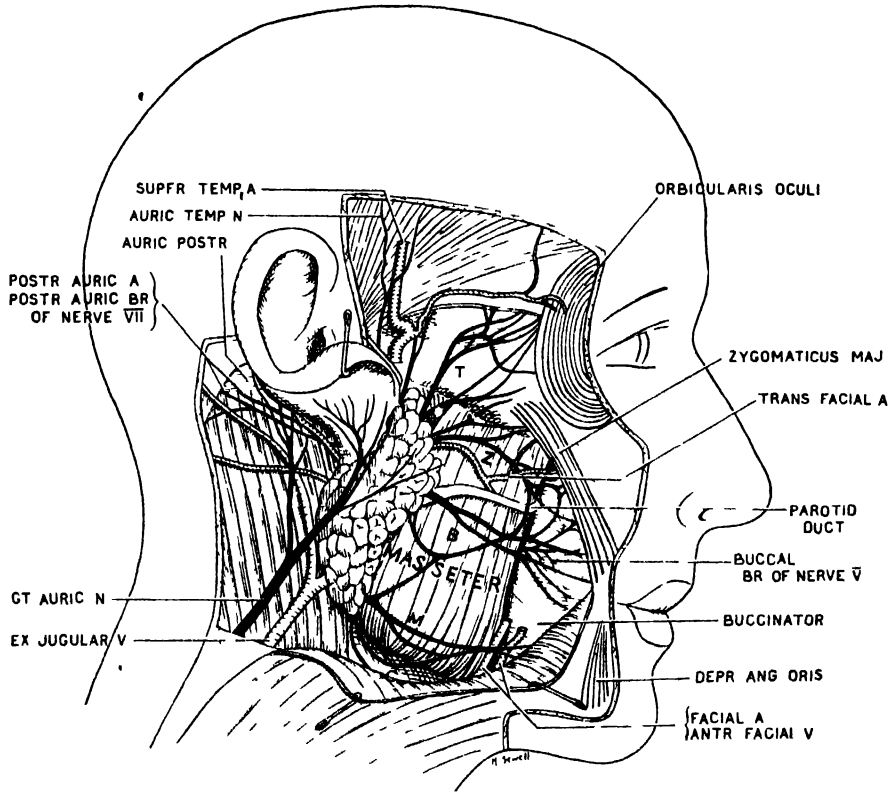


FIG. 622. Dissection of the side of the face.

Branches of the internal maxillary artery (mental and buccal) accompany the mental and buccal nerves; and the superficial temporal accompanies the auriculo-temporal nerve.

NOTE: The sensory pathway from (a) the *cornea* is via the ciliary nn. which travel between the scleral and choroidal coats of the eyeball; (b) from the *tip of the nose* via the external nasal n.; (c) from

are—the muscles of the face, auricle, and scalp, and the Platysma, (also— the posterior belly of the Digastric, the Stylo-hyoid, and the Stapedius).

Its terminal branches appear at the margins of the parotid gland and spread like the rays of an open fan. Of these. the *temporal branches* cross the zygomatic arch and supply all the muscles above it. The *zygomatic branches* pass

forwards above the parotid duct to supply the muscles of the infra-orbital region. The *buccal branch* takes the general direction of the buccal branch of the trigeminal nerve, but it is superficial to the Masseter. The *mandibular branch* supplies the muscles of the lower lip and chin.

The *cervical branches* are two in number. They pass within a finger's breadth of the angle of the jaw: one descends, anastomoses with the anterior cutaneous nerve of the neck, and supplies the Platysma; the other curves forwards, crosses the base of the jaw superficial to the *facial* (*external maxillary*) *artery*, joins the mandibular branch, and assists it to innervate the muscles of the lower lip.

The *posterior auricular branch* arises from the stem of the facial nerve. It crosses the mastoid and supplies the Occipitalis, Auricularis Posterior, and part of the Auricularis Superior. It is the only branch to pass backwards and it is of no importance.

These terminal branches are chiefly motor or efferent, but since they receive communications from the various sensory branches of nerve V on the face and from the 2nd and 3rd cervical nerves about the ear, scalp, parotid region, and neck, they are distributed ultimately as mixed efferent and afferent fibers.

The Blood Supply to the Face is extremely free and anastomoses are numerous. In addition to the many branches of the *ophthalmic* and *internal maxillary arteries* that accompany the various branches of the fifth nerve on to the face, there are the *facial* and *transverse facial arteries* (*fig. 612*).

THE FACIAL ARTERY (Ext. maxillary artery) appears on the face at the base of the jaw immediately in front of the Masseter. Its vein lies behind it on the Masseter; the cervical branch of the facial nerve enters the face superficial to it; one or two lymph glands lie beside it. In its tortuous course it passes about half-an-inch from the angle of the mouth and it ends at the side of the nose by dividing into the angular and the lateral nasal arteries. It crosses in turn the lower jaw, Buccinator, upper jaw, Levator Anguli Oris. And, it is crossed superficially by all the other muscles it encounters. In turn they are: Platysma, Risorius, Zygomaticus Major and Minor, and Levator Labii Superioris.

Branches: An *inferior* and a *superior labial branch* arise near the angle of the mouth and, with those of the opposite side, encircle the mouth between the Orbicularis Oris and the layer of labial glands. A *septal branch* springs from the superior labial a. Below the inferior labial a. a large *unnamed branch* runs on the jaw towards the mental foramen. Small twigs pass posteriorly. Of its two terminal branches, the *lateral nasal a.* follows the upper border of the lower nasal cartilage; the *angular a.* ascends on or through the Levator Labii Superioris Alaeque Nasi to the medial palpebral commissure and anastomoses with the dorsal nasal branch of the ophthalmic artery. The *submental branch* of the facial a. is large. It arises in the submandibular region and crosses the jaw near the chin to enter the face.

By palpation feel in your own body the pulsations of: (1) the main artery where it crosses the jaw, and (2) of the angular artery where it lies on the side of the bridge of the nose; by grasping the cheek or lip between the finger and thumb feel the pulse of (3) the main artery near the angle of the mouth, and of (4) the labial arteries within the margin of the lips.

THE SUPERFICIAL TEMPORAL ARTERY is one of the two terminal branches of the external carotid artery (*fig.

670). It arises deep to the parotid gland just behind the neck of the mandible. It crosses the posterior root of the zygoma and ascends with the auriculo-temporal nerve for one or two inches before dividing into an anterior and a posterior branch. These are tortuous, and in older persons their pulsations can be seen through the skin. They run superficial to the temporal fascia to enter the subcutaneous layer of the scalp, where they anastomose freely (*fig.* 626).

Branches: In addition to the two terminal branches for the scalp, branches are distributed to the face and temporal region and twigs to nearby structures (parotid gland, auricle, external auditory meatus, and jaw joint). The facial branch, the *transverse facial artery*, appears from under cover of the anterior border of the parotid gland, crosses the Masseter transversely between the zygoma and the parotid duct, and anastomoses on the face. The temporal branch, the *middle temporal artery*, crosses the zygoma, pierces the temporal fascia and temporal muscle, and ascends in a groove on the squamous temporal bone.

VEINS. The companion vein of the facial artery is called the *anterior facial vein*. It runs behind the artery taking a less tortuous and more superficial course. Its branches correspond to those of its artery. In addition, however, it receives the blood from the supra-orbital and supratrochlear veins. In fact, it is by union of these two veins that the anterior facial vein arises. It makes the three following important connections (*fig.* 628): (1) With the *pterygoid plexus* through the *deep facial vein.* This vein curves backwards below the zygomatic process of the maxilla and deep to the ramus of the jaw. It connects the anterior facial vein with the veins around the pterygoid muscles; these in turn communicate through the foramina at the base of the skull with the cavernous sinus. (2) With the *cavernous sinus* through the *superior ophthalmic vein.* This vein communicates in front with the supra-orbital and supratrochlear veins, and drains backwards into the cavernous sinus. (3) With the *diploic veins* through the *frontal diploic vein.* This vein emerges from a pin-point hole in the supra-orbital notch and joins the supra-orbital vein.

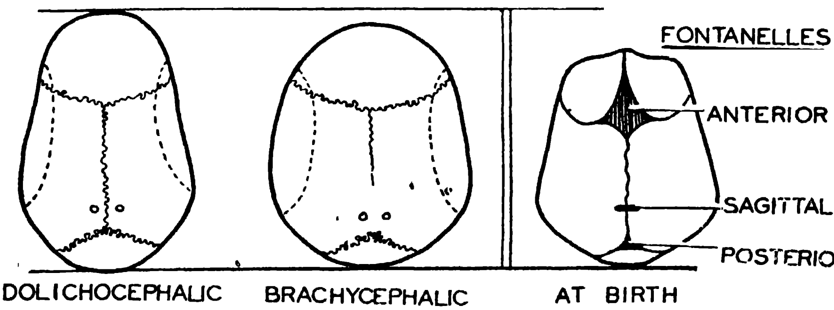


FIG. 623. Skulls viewed from above. (A) dolicho-cephalic = width less than 75 per cent of length; (B) brachy-cephalic = more than 80 per cent; (C) fontanelles or unossified areas at birth

THE SKULL FROM ABOVE AND THE SCALP

Norma Verticalis. Viewed from above, a skull is roughly oval in outline, but it may have one of many shapes. In front, a glimpse may be had of the bridge of the nose, but the face is not projecting (prognathous) as in lower animals. At

the sides, the zygomatic arches are hidden (cryptozygous) in white races, but visible in others, e g, certain Eskimos. Behind, the inion is not in view because it lies below the posterior pole of the skull.

When the maximum width of a skull is less than 75 per cent of its maximum length it is said to be dolicho-cephalic or long headed, when more than 80 per cent it is called brachycephalic or broad headed, when between 75 and 80 per cent it is mesaticephalic On this quantitative character anatomists have classified the races of mankind (*fig 623*).

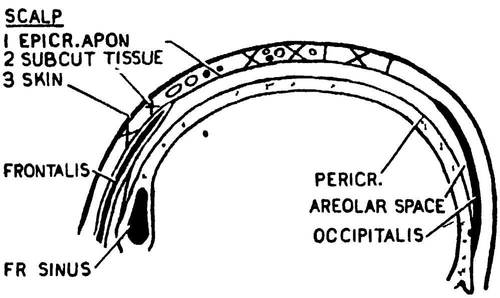


FIG 624 Sagittal section of skull-cap and overlying tissues. Note the fibrous bands, fat, vessels, and nerves in the scalp

Three sutures related to three sides of the parietal bone are visible: the coronal fronto-parietal), the sagittal (or interparietal), and the lambdoid (or parieto-occipital). The point of intersection of sagittal and coronal sutures is the *bregma*. The point of intersection of sagittal and lambdoid sutures is the *lambda*.

The bones of the roof of the skull develop in membrane, ossification beginning in the frontal and parietal bones during the second fetal month at their points of greatest fullness, called the *frontal* and *parietal eminences*. At birth, ossification has not reached any of the four angles of the parietal bones; so, at these sites, called *fontanelles*, the brain is covered with membrane. Of these, the *anterior fontanelle* is 1″ by 2″ in diameter and is shaped like a flat kite with the long angle tapering into the interfrontal or metopic suture. If not obliterated before the end of the 2nd year there is something amiss. The bregma marks the site. The summits of the temporal lines and the pinpoint parietal foramina are in view

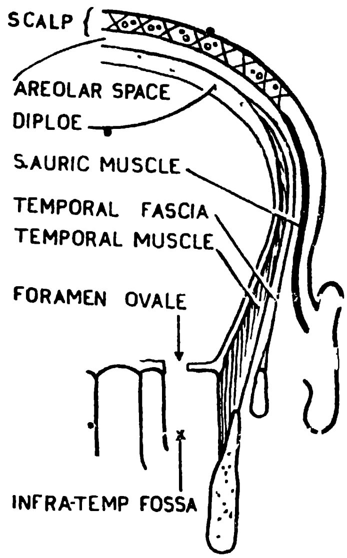


FIG. 625 Coronal section of head.

The Scalp is composed of skin, subcutaneous tissue, and Epicranius All three are firmly bound together and are separated from the skull by an areolar space (*fig. 624*). Phylogenetically, the Epicranius was a continuous muscle sheet, now aponeurotic save at its anterior and posterior ends. Its posterior muscular end, the *Occipitalis*, is attached to the superior nuchal line. Its anterior end, the *Frontalis*, extends right across the forehead blending with its fellow in the middle line and interdigitating in front with the Orbicularis Oculi. As the

Occipitalis has a fixed bony attachment while the Frontalis is free, contraction of the muscles draws the scalp backwards and causes horizontal wrinkles on the forehead. It may be called upon to assist feebly in raising the eyelids. Laterally, the ***Epicranial Aponeurosis*** gives origin to the superior and anterior auricular muscles, elsewhere it fades away over the temporal fascia (*fig. 625*). In the subcutaneous tissue, fibers run criss-cross in all directions, uniting skin to Epicranius. Between the fibers fat is imprisoned, and there the vessels and nerves run.

Nerves. Of the cranial nerves (bar the auricular twigs of the facial and vagus nerves) only the trigeminal (V) has cutaneous branches. Of the spinal nerves, the 1st cervical nerve sometimes resembles the last cranial nerve in that it loses the sensory root which it possessed in embryonic life.

Knowing this, you will appreciate that the sequence in which the sensory nerves appear in the scalp is an orderly one from front to back—V^1, V^2, V^3; anterior rami of cervical nerves 2 and 3; and posterior rami of cervical nerves 2 and 3 (*fig. 626*). Note that the supra-orbital nerves reach nearly to the lambdoid suture.

Arteries. The anastomosis between the arteries of the scalp is extremely free. These arteries are derived either indirectly from the internal carotid through its

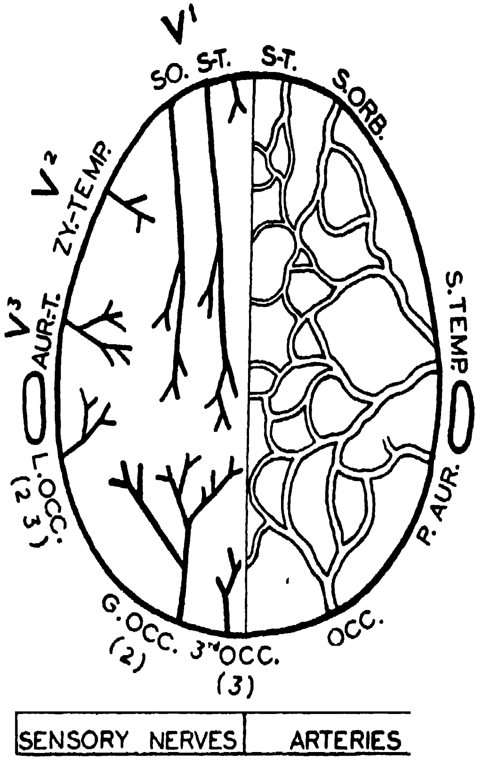


FIG. 626. The sensory nerves and the arteries of the scalp.

ophthalmic branch (viz., supratrochlear, supra-orbital) or directly from the external carotid (viz., superficial temporal, posterior auricular, occipital). (*Fig. 626.*)

CHAPTER 20

THE POSTERIOR TRIANGLE OF THE NECK

Boundaries. The middle third of the clavicle is the base of the triangle; the posterior border of the Sterno-mastoid is the anterior side; the anterior border of the Trapezius is the posterior side; the point where these two muscles meet on the superior nuchal line is the apex. Figure 48 will remind you that the clavicle also forms the base of the delto-pectoral triangle.

The posterior triangle is formed as the result of a longitudinal cleavage of what in embryonic life was a single muscle mass, now the **Sterno-Cleido-Mastoideus** and the Trapezius. Above, these two muscles have a continuous attachment extending from the inion to the tip of the mastoid process. This attachment is aponeurotic; so, it produces a ridge, the *superior nuchal line*. The mastoid process is the extremity of this line drawn out by the Sterno-mastoid; so, it takes the downward, forward, and medial direction of the pull of the Sterno-mastoid (*fig. 627*). Below, the two muscles have a discontinuous attachment to the clavicle, the Trapezius being attached to the posterior border of its flattened lateral third; the Sterno-cleido-mastoideus (clavicular head) to the superior border of its medial third. The sternal head crosses in front of the sterno-clavicular articulation and finds attachment to the sternum just below. It is fibrous, of course.

Action. Flex your head and neck, so that you are looking at your toes, and let your forehead rest in the palm of your hand. If you continue to flex against the resistance of your hand, your Sterno-mastoids will stand out and they may be palpated with your free hand. If now you rotate your bent head and neck, so that you look sideways up, the Sterno-mastoid of the opposite side will become still more prominent.

The Platysma is superficial to the lower part of the triangle (*page 650*).

The Investing Deep Fascia of the neck covers the posterior triangle and splits to envelop the Sterno-mastoid in front and the Trapezius behind. In obedience to the law that deep fascia does not cross bare bone but is attached to it except where some muscle, vessel, or nerve intervenes to detach it, it is found that the deep fascia is attached to the upper border of the middle third of the clavicle between the insertions of the Sterno-mastoid and Trapezius, that is, to the base of the posterior triangle. It is regarded as the roof of the triangle.

Crossing the triangle immediately deep to the fascial roof are the accessory nerve and branches of nerves C. 3 and 4.

The Spinal Part of the Accessory Nerve (N.XI) is the nerve to the Sterno-mastoid and Trapezius, and it spans the gap between them. It is the highest structure in the triangle, and it is placed very superficially—immediately deep to the investing fascia. The accessory nerve has a curious origin: arising from the upper 5 or 6 segments of the spinal cord, it enters the cranial cavity by the foramen magnum only to leave again by the foramen jugulare (*fig. 716, p. 716*). In the neck it passes obliquely downwards and backwards from the transverse process of the atlas to the superior angle

of the scapula (*fig. 78*). En route it disappears under cover of the anterior border of the Sternomastoid less than $2\frac{1}{2}$ inches below the tip of the mastoid process. Here lymph glands surround it. It reappears at what you would estimate to be the middle of the posterior border of this muscle. Here more lymph glands surround it, and the lesser occipital nerve takes a recurrent course below it. It then crosses the posterior triangle subfascially, superficial to the Levator Scapulae, and disappears again, this time under cover of the anterior border of the Trapezius, 2 to 3 fingers' breadth above the clavicle. Sensory twigs from C. 2, 3, and 4 join it in variable parts of its course.

The accessory nerve is the highest structure in the triangle, and it divides it into two nearly equal parts: in the part above the nerve you may dissect *carefree* for there is no important structure to damage; but below you must be *careful.*

Branches of Cervical Nerves 3 and 4 cross the posterior triangle subfascially a finger's breadth or less below and parallel to the accessory nerve, and they are apt to be mistaken for it. Some of these sensory branches pass deep to the Trapezius and enter it; others, *lateral branches of the supraclavicular nerves,* pass superficial to it. The intermediate and medial branches of the supraclavicular nerves also descend subfascially and cross the clavicle (*fig. 59*).

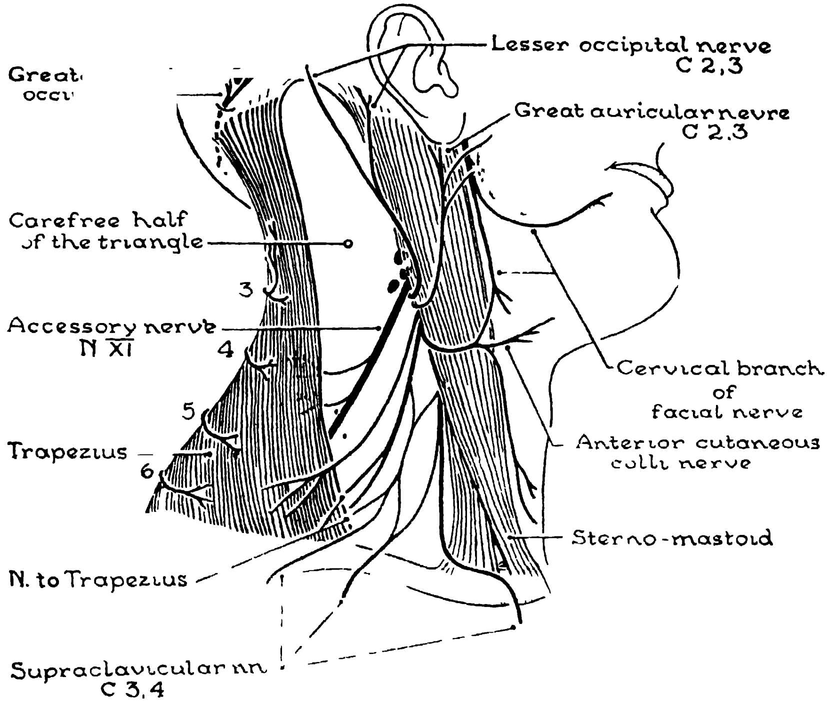


FIG. 627 The superficial nerves of the neck. Of these, the facial (VII) and accessory (XI) are motor

The Omohyoid is one of the depressor muscles of the larynx. During development a backward extension (the inferior belly) of this straplike muscle passed from the anterior to the posterior triangle and gained attachment to the upper

border of the scapula beside the suprascapular notch. It passed deep to the Sterno-mastoid and dragged its nerve after it.

The inferior belly of the Omohyoid rises one or two fingers' breadth above the clavicle. A layer of condensed areolar tissue binds it down to the fascia covering the Subclavius and forms an inverted sling for it. There is, therefore, a pouch between the "Omohyoid fascia" and the investing deep fascia. Sometimes the inferior belly does not extend beyond the clavicle. This inconstant belly is said to divide the posterior triangle into a small *subclavian triangle* and a large *occipital* one.

The External Jugular Vein (*fig. 628*) descends subplatysmally across the Sterno-mastoid, pierces the investing deep fascia at the posterior border of the Sterno-mastoid an inch above the clavicle, pierces the fascia retaining the Omohyoid, and ends in the subclavian vein.

Branches. The *transverse cervical, suprascapular,* and *anterior jugular veins* communicate with each other in the pouch between the investing deep fascia and the fascia retaining the Omohyoid, and end in the external jugular vein. The terminal part of the anterior jugular vein lies along the upper border of the clavicle deep to the Sterno-mastoid.

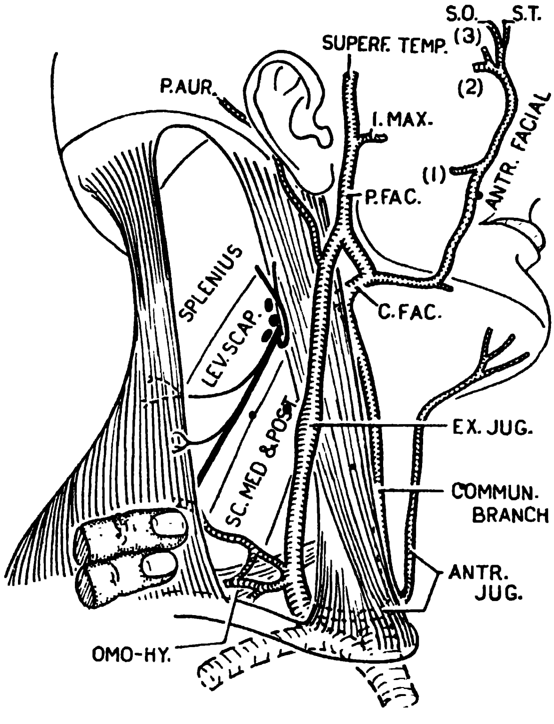


FIG. 628. The superficial veins of the face and neck. Note connections with (1) pterygoid plexus, (2) ophthalmic veins and therefore cavernous sinus, and (3) frontal diploic vein.

The Floor of the Triangle is formed by several muscles whose fibers run obliquely downwards and backwards. Of these, the *Levator Scapulae* occupies a somewhat central position. It arises from the posterior tubercles of the transverse processes of the upper four cervical vertebrae,

and it is inserted into the vertebral border of the scapula between the root of the spine and the superior angle. The accessory nerve is superficial to it, parallel to its fibers, and serves as a guide to it. Above the Levator and parallel with it is the soft-grained *Splenius Capitis*. Below the Levator and parallel with it are the three Scaleni (*fig. 702*). Of these, the *Scalenus Medius* arises from the posterior tubercles of all the cervical transverse processes (2, 3, 4, 5 and 6) except the first and last, and it is inserted into the upper surface of the first rib between the groove for the subclavian artery and the neck of the rib. The *Scalenus Posterior* may be considered as the portion of the Medius that passes on to the second rib. The *Scalenus Anterior* is separated from the Scaleni Medius and Posterior by the brachial plexus and the subclavian artery. It arises from the anterior tubercles of all the transverse processes that possess anterior tubercles, namely, 3, 4, 5 and 6. Its posterior border is parallel with the posterior border of the Sterno-mastoid, and lies so slightly behind it that it barely appears in the triangle. Follow its posterior border downwards to the insertion of the muscle into the scalene tubercle of Lisfranc, which is situated on the upper surface of the first rib between the groove for the subclavian vein in front and the groove for the subclavian artery behind. The lateral border of the 1st rib forms the lower limit of the floor, and there the subclavian artery becomes the axillary artery. The digitation of the *Serratus Anterior* that arises from the first rib therefore forms part of the floor. A small part of the *Semispinalis Capitis* may

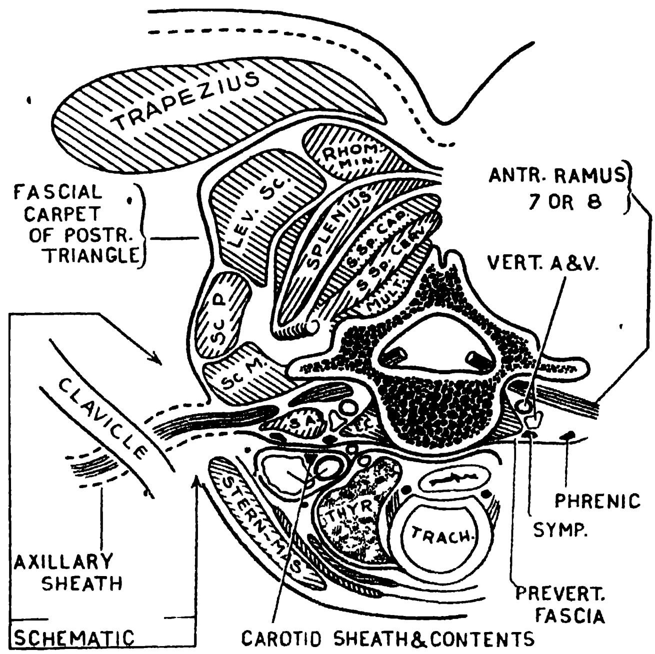


FIG. 629. Transverse section of the neck showing the pre- and post-vertebral fasciae prolonged into the axilla as a tubular covering (axillary sheath) for the brachial plexus and subclavian vessels. The nerves shown in figure 630 remain deep to this fascia.

appear at the apex of the triangle above the Splenius. It is told by its vertically running fibers. It is crossed by the occipital artery (*fig. 639*).

The Fascial Carpet. The muscular floor is carpeted with a layer of fascia. This fascia is part of the pre- and post-vertebral fasciae that envelope like a sleeve the vertebral column and the pre- and post-vertebral muscles. Of course, the cervical nerves leaving the intervertebral foramina, and the subclavian vessels leaving the thorax, are at first deep to this carpet. The carpet covers the subclavian vessels and the roots of the brachial plexus and it provides them with a tubular sheath, the *axillary sheath*, as they enter the axilla (*fig. 629*). It also covers the motor nerves to 4 important muscles—Levator Scapulae, Rhomboids, Serratus Anterior, and Diaphragm. Now, these nerves are safe and cannot be damaged so long as the fascial carpet is left intact, for having no occasion to pierce the carpet they course between it and the muscles of the floor.

The Danger Area in the Posterior Triangle. From what has been said it should be clear that the area of danger lies below the level of (caudal to) the accessory nerve and deep to the plane of the fascial carpet. (1) To find the nerve you must know its surface anatomy. (2) To find the carpet you must use either your fingers or two pairs of blunt forceps.

The Great Vessels. The subclavian vessels and the brachial plexus are the most important structures in the posterior triangle of the neck. Really they belong to the upper limb, the clavicle being an artificial barrier between the neck and the limb. As the vessels and the plexus pass downwards behind the clavicle and Subclavius, their sheath becomes attached to the sheath of the Subclavius (clavipectoral fascia) (*fig. 60*).

The Subclavian Vein is the continuation of the axillary vein. It begins at the lateral border of the 1st rib and ends at the medial border of the Scalenus Anterior by joining the internal jugular vein to form the innominate vein. The vein is separated by the Scalenus Anterior from its artery; both vessels groove the 1st rib. The rib is obliquely set; so, the vein lies antero-inferior to the artery, and it does not rise above the clavicle.

It has one tributary, the *external jugular vein*, and perhaps another, the *thoracic* (or right lymph) *duct*, which opens into its angle of union with the internal jugular vein. At its junction with the axillary vein there is a valve, and there is no valve between this and the heart.

The Subclavian Artery and the brachial plexus appear through the floor between the Scaleni Anterior and Medius.

The 3rd part of the artery extends from the lateral border of the Scalenus Anterior to the lateral border of the 1st rib where it becomes the axillary artery. The axillary artery has been seen to pass within a finger's breadth of the tip of the coracoid process (*p. 85*).

Mapped on the skin, the artery runs from a point just behind the posterior border of the Sterno-mastoid and a finger's breadth above the clavicle towards a point a finger's breadth medial to the tip of the coracoid. This line crosses the midpoint of the clavicle.

Below it are the 1st rib and the pleura.

Behind it are Scalenus Medius and the lowest trunk of the brachial plexus.

In front of it are: the Platysma, cutaneous nerves, three layers of fascia, and a plexus of veins; the clavicle, Subclavius, and the suprascapular artery; and the subclavian vein is antero-inferior.

Branches. The 3rd part of the artery has no regular branch, but in about 10 per cent of limbs either the transverse cervical

a., or its deep branch, or the suprascapular a. arises from it (*fig. 679*).

The Brachial Plexus (*fig. 630*). *Terminology.* In the thoracic, lumbar, and sacral regions the spinal nerves are named numerically after the vertebrae above them. In the cervical region, however, they are named after the vertebrae below them. What of the nerve between the 7th cervical and 1st thoracic vertebrae? It is grouped with the cervical nerves, making the 8th. So, there are 8 cervical nerves, but only 7 cervical vertebrae.

The Transverse Processes of the cervical vertebrae have a downward tilt due to the pull of muscles and each possesses a posterior tubercle. Anterior tubercles are absent from the first, second, and seventh cervical transverse processes and present on the 3rd, 4th, 5th, and 6th; and the width of the groove between anterior and posterior tubercles depends on the size of the anterior ramus around which the process is moulded, and it increases from 3rd to 6th (*fig. 632*). These facts assist in the reassembling of disarticulated vertebrae.

The upper limb originally occupied the level of the segments from which it derives its nerves; but it descends, dragging them after it. This accounts for the obliquity of the plexus.

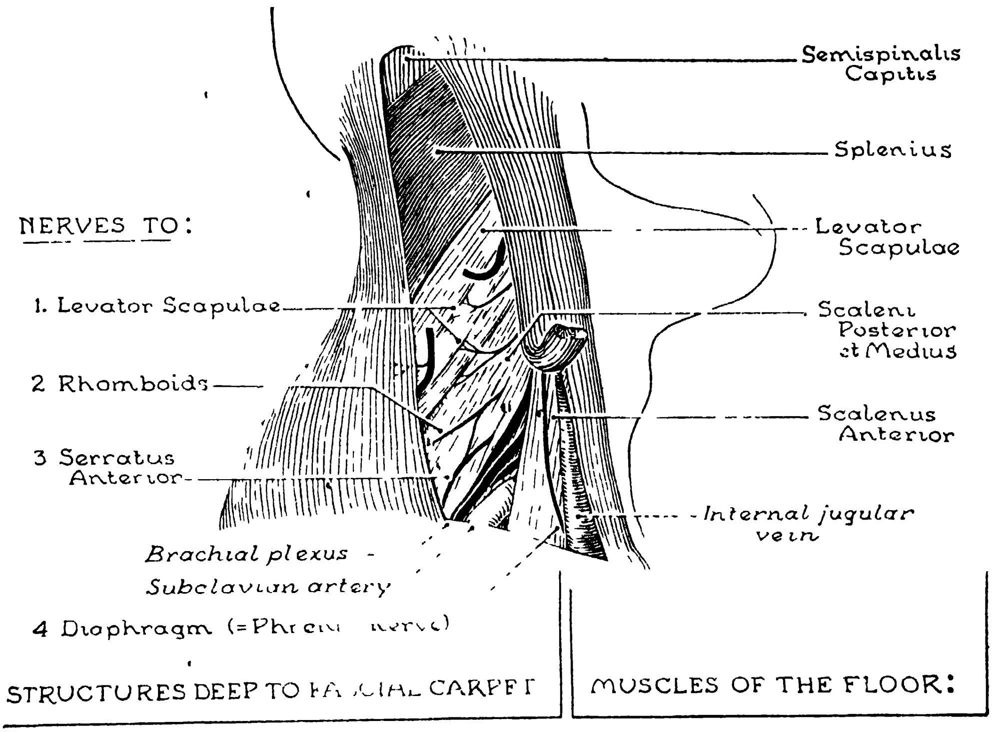


FIG. 630 The floor of the posterior triangle and the nerves that have no occasion to pierce its fascial carpet.

The Brachial Plexus is formed by the anterior rami of nerves C. 5, 6, 7, and 8 and Th. 1. The anterior ramus at each end of the series, namely, C. 4 and Th. 2, commonly contribute branches. Occasionally the plexus is moved more or less bodily a segment headwards (prefixed) or tailwards (postfixed).

Rami 5, 6, and 7 take descending courses, 8 runs horizontally, 1 ascends. The rami increase in size from each end of the series to C. 7, which is the middle and largest ramus of the plexus. The cervical pleura rises in front of ramus Th. 1 to the level of ramus C. 8 (*fig. 690*). The plexus begins in front of the Scalenus Medius as five anterior rami and ends at the lower border of the Pectoralis Minor as five nerves (musculo-cutaneous, median and ulnar; circumflex and radial).

The plexus is composed as follows (*fig. 65*): rami 5 and 6 unite to form an uppermost trunk; ramus C. 7 continues as a middle trunk; rami C. 8 and Th. 1 unite at the neck of the 1st rib to form a lowest trunk. The lowest trunk lies on the first rib behind the subclavian artery and is in part responsible for the groove often attributed to the artery. Each of the three trunks divides into an anterior and a posterior division. Behind the clavicle the three posterior divisions unite to form the posterior cord of the plexus, whilst the upper and middle anterior divisions unite to form the lateral cord, and the lowest anterior division continues as the medial cord. The three cords of the plexus are disposed around the second part of the axillary artery, that is, behind the Pectoralis Minor, a finger's breadth from the tip of the coracoid process.

The roots of the plexus supply the Rhomboids, Serratus Anterior, Subclavius, and Diaphragm in part. They also supply the neighboring prevertebral muscles and they receive gray rami from the middle and inferior cervical sympathetic ganglia (*fig. 766*).

If the handle of the knife is carried along the lateral border of the plexus, it will be led away by the most lateral branch of the plexus, the ***suprascapular nerve***, to the suprascapular notch at the root of the coracoid process.

The Nerves to 4 Muscles– Levator Scapulae, Rhomboidei, Serratus Anterior, and Diaphragm– course between the muscular floor of the triangle and its fascial carpet. The nerves to the first three are to be found between the accessory nerve above and the upper border of the brachial plexus below. They arise from the posterior aspects of anterior nerve rami, and they join in the general infero-lateral slope. Thus:

(1) A branch from C. 3 and one from C. 4 arise with the roots of the supraclavicular nerves, descend on the *Levator Scapulae*, and supply it within the triangle.

(2) A branch from C. 5 supplies the *Rhomboids* and sends a twig to the Levator Scapulae. It crosses the Scalenus Medius, usually after piercing it, and disappears deep to the anterior border of the Levator Scapulae.

(3) Branches from C. 5, 6, and 7 supply the *Serratus Anterior*. Those from C. 5 and 6 join and cross the Scalenus Medius, usually after piercing it, with or just below the nerve to the Rhomboids. Branch C. 5 ends mainly in the highest digitation of the Serratus; branch C. 6 enters the axilla applied to the Serratus. Branch C. 7 is concealed by the brachial plexus which shelters it from danger. To find it, pull the plexus forwards and seek for a long, stout thread which leaves trunk C. 7 and descends behind it. This thread crosses in front of the Medius, passes on to the Serratus Anterior, and remains applied to it as far as its lowest digitation. It enters the axilla behind the brachial plexus and great vessels and is there joined by branch C. 6.

(4) **The Phrenic Nerve** is not within the geometrical limits of the triangle, but it is in danger of injury when the Sterno-mastoid is retracted; so is the internal jugular vein, which descends in front of

the phrenic nerve. It would be an omission not to mention these important structures. The phrenic nerve arises from the anterior ramus of C. 4 and gets twigs from C. 3 and 5. It descends vertically on the Scalenus Anterior and is in naked contact with it, because having no occasion to pierce the prevertebral fascia, it remains deep to it.

Very liable to damage, because it pierces the fascial carpet early, is the important nerve (C. 5 and 6) to the unimportant *Subclavius*. This long thread commonly delivers to the phrenic nerve the contribution from C. 5. Hence, it is surgically important. *The nerve to the Subclavius* and its contribution to the phrenic nerve descend in front of the brachial plexus and subclavian vessels; whereas the phrenic nerve descends between subclavian artery and vein and receives the contribution beyond them.

Arteries and Lymph Glands. The *suprascapular* (transverse scapular) and *transverse cervical arteries* spring from the 1st part of the subclavian artery via the thyro-cervical trunk (*fig. 679*). They pass in front of the Scalenus Anterior and the fascia covering it, and they clamp the phrenic nerve in place. The former runs behind the clavicle to the suprascapular notch. The latter lies at a higher level and splits at the anterior border of the Levator Scapulae into two branches, of which one accompanies the accessory nerve and therefore passes superficial to the Levator; the other accompanies the nerve to the Rhomboids and therefore passes deep to the Levator.

Either of these arteries or one of the branches of the transverse cervical a. may arise from the 2nd or 3rd part of the subclavian artery, and any of them may thread its way among the branches of the plexus.

There may be a quantity of fat between the fascial roof of the triangle and the fascial carpet. In it are the inferior deep cervical (supraclavicular) *lymph glands*. They drain the back of the scalp and neck and they usually receive some efferent vessels from the upper deep cervical, axillary, and delto-pectoral glands. These glands empty into the jugular lymph trunk. The axillary glands empty into the subclavian lymph trunk, which follows the subclavian vein to the thoracic (or right lymph) duct.

Cutaneous Nerves (*fig. 627*). Because nerve C. 1 has no cutaneous branch and because the anterior rami of C. 5——Th. 1 are carried bodily into the upper limb, as the brachial plexus, it falls to the anterior rami of C. 2, 3, and 4 to supply the cutaneous territory between the trigeminal nerve above and the 2nd thoracic nerve below (*fig. 527*). This they do by means of four nerves that radiate from about the middle of the posterior border of the Sterno-mastoid. Thus:

(1) *The Lesser Occipital N*.(C. 2) hooks round the accessory nerve and ascends near the posterior border of the Sterno-mastoid. It gives off side branches and ends in the scalp.

(2) *The Great Auricular N*. (C. 2, 3) runs across the Sterno-mastoid towards the front of the lobe of the ear. It is either in contact with the external jugular vein or at some distance behind it. *Mastoid* branches pass to the skin of the mastoid region; *auricular* branches pass to the cranial surface of the auricle and to the lower part of its lateral surface; *facial* branches pass to the skin covering the parotid gland and Masseter, and branches *anastomose* with the facial nerve.

(3) *The Anterior Cutaneus Colli N*. (C. 2, 3) crosses the Sterno-mastoid transversely near its middle and supplies the skin between the jaw and the sternum. It does so through two main branches: of

these, one runs upwards along the anterior border of the Sterno-mastoid and communicates with the cervical branch of the facial nerve; the other runs downwards along this border. The end twigs pierce the Platysma. The stem of the nerve passes either superficial or deep to the external jugular vein.

(4) *The Supraclavicular Nerves* (C. 3, 4) arise from a common stem that divides into three branches: the *medial* branch descends along the posterior border of the Sterno-mastoid to the clavicle, turns forwards and pierces the Platysma; the *intermediate* branch descends, divides, and crosses the middle third of the clavicle, and pierces the Platysma; the *lateral* branch runs parallel to the accessory nerve and a little below it and passes superficial to the Trapezius. The supraclavicular nn supply the skin covering the lower part of the posterior triangle and the acromial region and also the skin covering the Pectoralis Major and Deltoid above the level of the 2nd rib.

THE BACK

The Muscles of the back of the head and trunk are arranged in superficial, intermediate, and deep groups. The *superficial group* acts upon the limbs; the *intermediate group* is respiratory in action; and both have migrated or spread backwards across the deep group of muscles. This is indicated by their nerve supply—the accessory nerve and anterior nerve rami. The *deep group* is intrinsic to the back; it is composed of "native" muscles supplied by posterior nerve rami.

Superficial

(1) Trapezius and Latissimus Dorsi.

(2) Levator Scapulae and Rhomboidei.

Intermediate

(3) Serrati Posteriores (superior et inferior) (*fig. 634*).

Deep

(4) Splenius (cervicis et capitis).

(5) Longitudinal muscles or Sacrospinalis (Ilio-costo-cervicalis; Longissimus; Spinalis).

(6) Oblique muscles (Semispinalis; Multifidus; Rotatores).

(7) Remaining muscles (Interspinales, Intertransversales; Levatores Costarum;[1] Suboccipital muscles).

The Skeletal Parts covered by the deep or intrinsic muscles are: (a) the nuchal region of the skull; (b) the dorsal aspect of the vertebral column, and the ribs between the tubercles and angles; and (c) the posterior three inches of the iliac crest. These you should examine in the articulated state prior to, and concurrently with, your examination of the soft parts.

The Skull Viewed from Behind: Norma Occipitalis. THE OUTLINE of the norma occipitalis is horseshoe-shaped and extends from the tip of one mastoid process over the vault to the tip of the other (*fig. 631*). On each side it crosses in turn the supramastoid crest, parieto-mastoid suture, parietal eminence, and temporal lines. At the base of the skull the outline extends nearly horizontally from one mastoid process to the other, except where the condyles project downwards. Medial to the mastoid process the outline crosses two grooves: the lateral one gives origin to the posterior belly of the Digastric; the medial one lodges the occipital artery. It then crosses the occipito-mastoid suture, the jugular process of the occipital bone, the occipital condyle and the foramen magnum.

THE SURFACE of the norma occipitalis is convex and includes parts of the parietal, occipital, and temporal bones.

[1] The Levatores Costarum are supplied by anterior rami (see p. 504, and fig. 525).

At the center is the *lambda*. From it a *triradiate suture* runs: the sagittal (interparietal) suture to the vertex, the lambdoid (parieto-occipital) suture to the blunt postero-inferior angle of the parietal bone on each side. There the lambdoid suture divides into two limbs: one limb continues downwards and forwards as the *occipito-mastoid* suture to the root of the styloid process; the other runs forwards as the parieto-mastoid suture. On each side there are *three foramina* for emissary veins: (1) the parietal foramen situated close to the

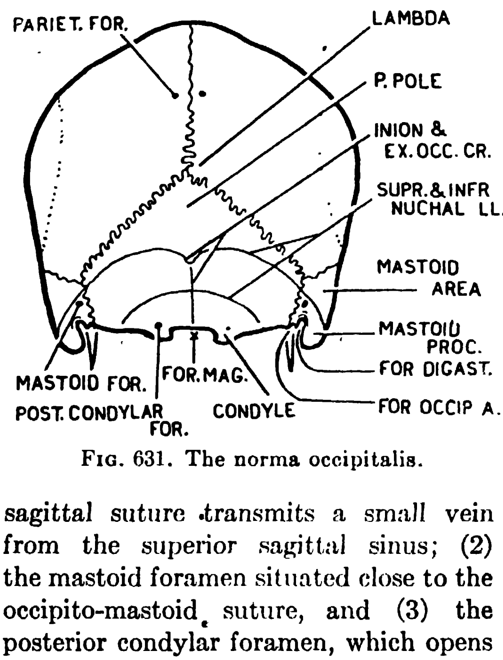


FIG. 631. The norma occipitalis.

sagittal suture transmits a small vein from the superior sagittal sinus; (2) the mastoid foramen situated close to the occipito-mastoid suture, and (3) the posterior condylar foramen, which opens on to the posterior condylar fossa, transmit veins from the sigmoid sinus. Any of the three may be absent. (Meningeal twigs of the occipital artery traverse the mastoid and parietal foramina.) The posterior condylar fossa receives the rim of the articular process of the atlas when the head is extended. Midway between the lambda and the foramen magnum is the *inion* or *external occipital protuberance*. From it the *superior nuchal line* curves to the rough lower half of the outer surface of the mastoid process, which indeed is the drawn out end of the superior line. The Trapezius creates the medial $\frac{1}{3}$ of the line; the Sterno-mastoid and Splenius Capitis create its lateral $\frac{2}{3}$ and draw out the process. The surface below the superior nuchal line is the *nuchal area*, or area for the muscles of the neck (nucha = neck). The surface above is divided unequally into the ***scalp area***, ***mastoid area***, and ***temporal fossa***.

The nuchal area is the one that particularly concerns you at the moment. When the neck muscles are massive, the inion and the superior nuchal lines mount high; but normally the positions of the external (inion) and internal occipital protuberances almost correspond The *external occipital crest* is a sharp crest that gives attachment to the ligamentum nuchae and runs from the inion to the foramen magnum. The *inferior nuchal line* curves laterally from the midpoint of the external occipital crest and lies midway between the superior nuchal line and the foramen magnum.

When one falls on the back of one's head it is not the inion that strikes the ground but the *posterior pole* of the skull, which lies an inch or so above the inion.

The Articulated Vertebral Column Viewed from Behind. The articulated column is seen as two longitudinal gutters, one on each side of the middle line. Each gutter extends from the tips of the spinous processes to the tips of the transverse processes. Consider the elements of the gutter one by one:

SPINOUS PROCESSES. Of the various spinous processes C. 1 (the atlas) is reduced to an upturned tubercle—a spine here would interfere with extension of the head; C. 2–C. 6 are bifid in white races; C. 7 (the vertebra prominens) is less prominent than Th. 1; Th. 5–8 (the

middle 4 thoracic spines, situated behind the pericardium) are almost perpendicular, and are markedly overlapping; Th. 10 is often disproportionately small; Th. 11 (the anticlinal vertebra) is directed horizontally backwards, and the spines above it and below converge on it; the lumbar spinous processes are oblong plates; the upper three or four sacral spines form a median crest; the lower sacral and the coccygeal spines are missing. Supraspinous and interspinous ligaments unite the spines. In the neck the supraspinous ligament is the *ligamentum nuchae* It is triangular. Its posterior border is free; its anterior border is attached to the cervical spines; its superior border is attached to the inion and external occipital crest. The pull of the ligamentum nuchae and Trapezius account for the direction of the inion.

The Laminae are bandlike and tend to overlap the laminae below—testudo fashion. They are united to each other by ligamenta flava. Their infero-lateral angles carry the inferior articular processes. These remarks do not hold for laminae C. 1, known as the *posterior arch of the atlas*, which is slender, compressed from above downwards, and grooved above on each side by the corresponding vertebral artery. Above and below the posterior arch of the atlas there is a wide interlaminar space closed by membranes (posterior atlanto-occipital and atlanto-axial). The lumbar interlaminar spaces also are wide. Flexion of the spine, of course, enlarges all interlaminar spaces. The upper sacral laminae are fused. The lower sacral and the coccygeal laminae are absent; so, the posterior surfaces of the bodies of these vertebrae are exposed.

The Articular Processes partaking in the atlanto-occipital and atlanto-axial joints lie on a plane anterior to the subsequent articular processes and are not serially homologous with them (*fig. 632*). The subsequent cervical articular processes are segments of a column cut obliquely. Note particularly that the cervical articular processes afford attachment to the posterior roots of the transverse processes. The inferior articular

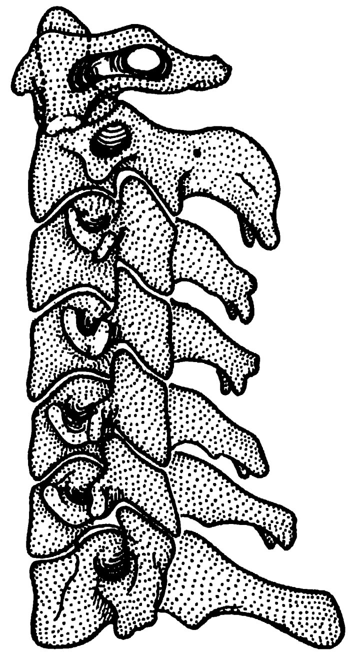


Fig. 632. Cervical vertebrae on side view.

processes are visible from behind in all regions. The posterior margins of the superior articular processes of the atlas and axis and of the lumbar and first sacral vertebrae are visible from behind. The sacral articular processes amalgamate on each side to form an interrupted *crest of articular tubercles*. It lies medial to the posterior sacral foramina and it ends below as a *sacral cornu*, which by articulating with the corresponding *coccygeal cornu* completes a foramen for the 5th sacral nerve (*fig. 633*). On extension of the spine the lower borders of the inferior articular processes engage in pits.

THE TRANSVERSE PROCESSES of C. 1 and C. 7 project far beyond those of C. 2–6, which are just visible beyond the articular processes (*fig. 701*). Th. 1–12 diminish progressively in projection. L. 1–5 project farther than C. 1 and C. 7, L. 3 being the most projecting of all transverse processes. L. 5 lies below the level of the iliac crest and, due to its special function, is stout, directed upwards and backwards, and is conical (*p. 332*). The sacral transverse processes

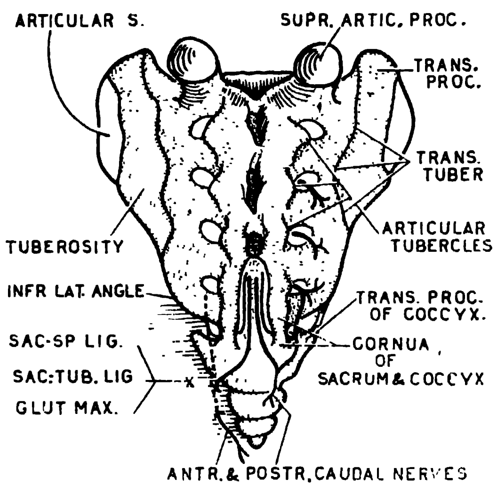


FIG. 633. The posterior aspect of the sacrum and coccyx.

form an irregular crest of *transverse tubercles* which ends below as the *inferolateral angle of the sacrum.* A ligament, commonly ossified, joins this angle to the *transverse process of the coccyx,* thereby forming a foramen for the anterior ramus of the fifth sacral nerve.

THE POSTERIOR SACRAL FORAMINA are 4 in number on each side. They are sharp and round and admit a lead pencil. They lie between the articular and transverse tubercles. They communicate in front with the anterior sacral foramina and medially with the sacral canal. The lead pencil passes straight forwards through the anterior sacral foramina to the front of the sacrum.

THE RIBS. The distance between the tubercles and angles of the ribs diminishes from below upwards; and they meet on the 1st rib. The backward tilt of the thoracic transverse processes allows the ribs to curve backwards almost as far as the spinous processes. Here they are twisted to form angles, and are marked by lines resulting from the attachment of the Ilio-costo-cervicalis. Owing to the downward slope of the ribs, the angles lie on nearly the same horizontal plane as the tips of the spinous processes with which they correspond numerically.

A lumbar transverse process is morphologically a costal or rib element; and, a tubercle, called the *accessory process,* situated behind its root is in series with the thoracic transverse processes and posterior roots and tubercles of the cervical transverse processes, i.e., it is the morphological transverse process (*fig. 28*). It gives insertion to slips of the Longissimus and; so, is pulled downwards. On the back of the rim of each lumbar superior articular process there is a tubercle, the *mamillary process.* It gives origin to the Multifidus and is therefore pulled upwards. The transverse processes of the 11th and 12th thoracic vertebrae do not support ribs; so, they are rudimentary. The 11th and 12th vertebrae have mamillary processes; and the 12th has also an accessory process.

THE ILIAC CREST. The hinder three inches of the iliac crest lies above the rough area (tuberosity) for the strong interosseous sacro-iliac ligament and is therefore medial to the smooth iliac fossa. It gives origin to the Sacrospinalis and therefore belongs to the region of the deep muscles of the back.

The Intermediate Muscles of the Back and the Splenius. It is profitless to

memorize even for a short period the text book description of the attachments of that you should not neglect to obtain a grasp of the scheme of things by making

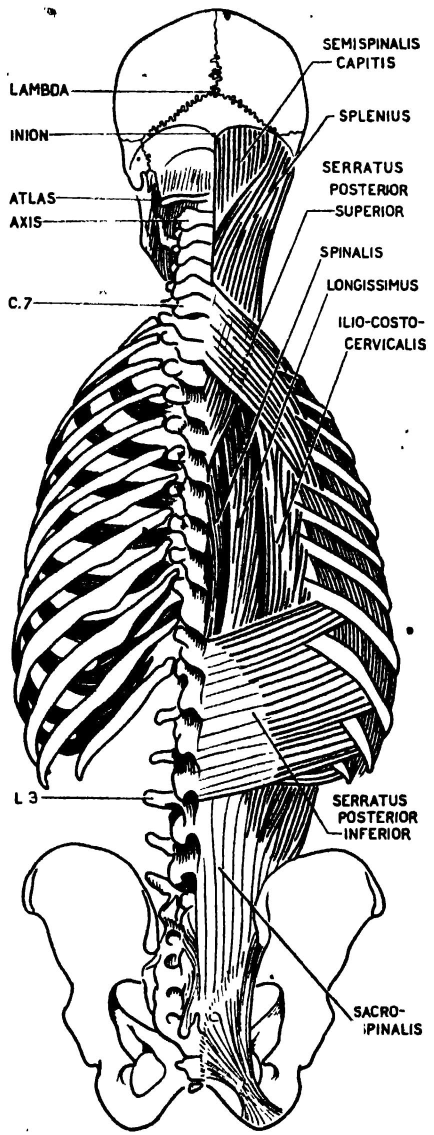


FIG. 634.

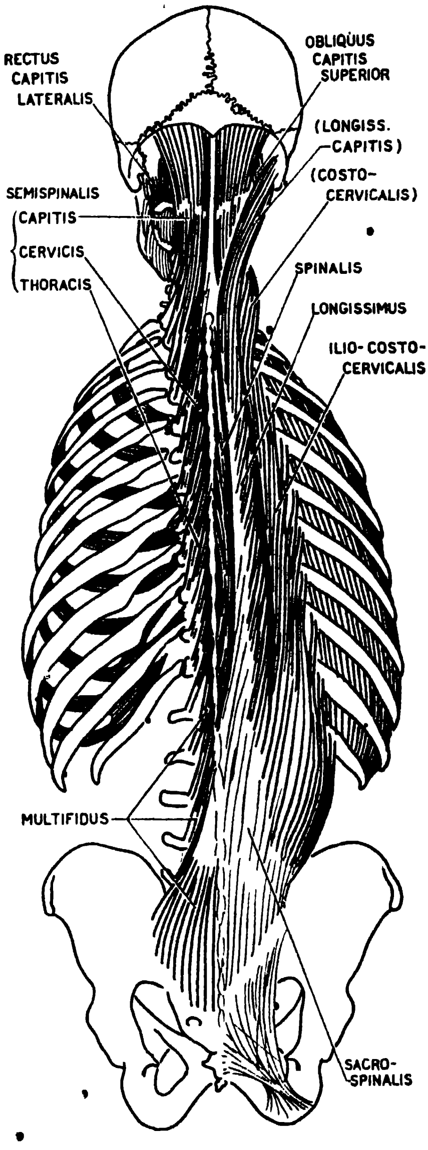


FIG. 635.

FIG. 634. The "intermediate" muscles of the back. (Dissection by Dr. V. P. Collins.)
FIG. 635. The "deep" or intrinsic muscles of the back. (Dissection by Dr. V. P. Collins.)

the numerous deep vertebral muscles, because you can make no use of the particular information. The back is, however, a region of such great importance a careful dissection. If the part is moist and the knife sharp, you can rapidly trace the tendinous slips of the muscles to their attachments and make a pretty dis-

play, because there is no fat here. The tough subcutaneous tissues at the back of the neck and the fascia of the sub-occipital region cause delay in the dissection of the nerves. You should certainly make the following observations.

The deep muscles (longitudinal, oblique and others) are bridged by the *Serrati* in the thoracic region, by the *lumbar* (lumbo-dorsal) *fascia* in the lumbo-sacral region, and by the *Splenius* in the cervical region and they cannot be viewed till these have been detached from the spines in the respective regions.

THE SERRATUS POSTERIOR has a superior and an inferior part. Each part has four slips with aponeurotic origins and fleshy insertions. The *Serratus Posterior Superior* arises from the lower cervical and upper thoracic spines and passes downwards and laterally to the upper ribs (2–5) beyond their angles. The *Serratus Posterior Inferior* blends with the lumbar fascia and through it gains attachment to the upper lumbar and lower thoracic spines. It passes transversely to the lower ribs (9–12) lateral to their angles. Both parts of this muscle elongate the thoracic cavity and so act as muscles of inspiration. They have migrated medially superficial to the deep muscles and are supplied by anterior nerve rami. Phylogenetically they form a continuous muscle sheet.

THE SPLENIUS is a specialized and detached part of the deep group of muscles which it has come to bridge. In fact, it is wrapped around them as its name implies (splenius L. = a bandage). It arises from the lower half of the ligamentum nuchae and from the upper thoracic spines (Th. 1–6). Its fibers pass semi-spirally upwards and laterally and separate into two parts, the Splenius Cervicis and Splenius Capitis. *The Splenius Cervicis* passes deep to the Levator Scapulae and shares its attachment to the cervical vertebrae (posterior tubercles C. 1–3 or 4). *The Splenius Capitis* passes deep to the Sterno-mastoid and shares its attachment to the superior nuchal line and mastoid process. It forms the floor of the posterior triangle of the neck above the Levator Scapulae.

THE LUMBAR (LUMBO-DORSAL) FASCIA is the dorsal aponeurotic attachment of the Transversus Abdominis (*figs. 286, 300*). Just as the Obliquus Abdominis Internus splits to form a sheath for the Rectus Abdominis, so the posterior aponeurosis of the Transversus Abdom-

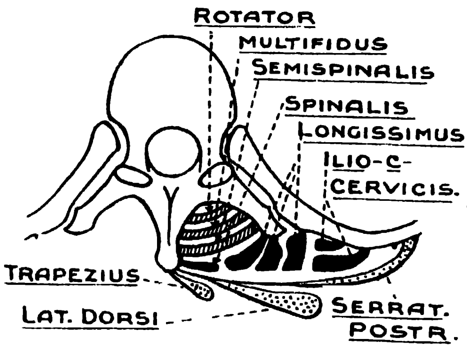


FIG. 636. The muscles of the back on cross section (schematic). Note: the deeper the muscle the shorter its span and the nearer it is to the vertebral canal.

inis splits to form a sheath for the deep vertebral muscles; and its fibers run transversely. *Its superficial layer,* called the posterior lamella of the lumbar fascia, is tough and thick. It passes behind the deep muscles to be attached to the lumbar spines. It can be traced downwards to the sacral spines, coccyx, transverse tubercles of the sacrum, crest of the ilium, and adjacent ligaments. The Latissimus Dorsi and Serratus Posterior Inferior reinforce it. It can be traced upwards as an areolar membrane (the vertebral fascia) to the skull. *Its deep layer* passes between the deep muscles and the Quadratus Lumborum

to be attached to the tips of the lumbar transverse processes, and also to the last rib above and to the iliac crest below. This layer, called the middle lamella of the lumbar fascia, is a strong, thin aponeurosis like the popliteal fascia. A thin areolar membrane, which covers the Quadratus Lumborum in front, is known as the anterior lamella of the lumbar fascia.

The Deep or Intrinsic Muscles (*fig. 636*). THE LONGITUDINAL GROUP OF MUSCLES, called the *Sacro-spinalis* (Erector Spinae), has: (1) a dense aponeurotic origin which is practically co-extensive with the attachment of the posterior lamella of the lumbar fascia covering it, and (2) a fleshy origin from the interosseous sacro-iliac ligament and the part of the iliac crest above it. A little below the last rib the Sacro-Spinalis splits into 3 longitudinal columns named: Ilio-costo-cervicalis, Longissimus, and Spinalis.

Observations. More tendinous slips than can be accommodated endeavor to find attachment, one behind the other, on the posterior tubercles of the cervical transverse processes; so, the hindmost are crowded on the articular processes whose close proximity makes this simple (*figs. 637, 638*).

The Ilio-costo-cervicalis (ilio-costalis, costalis, and costo-cervicalis) is inserted into the angles of the ribs and to the cervical transverse processes (C. 4–6) by a series of relayed bundles that extend over about six segments; where one slip is inserted another slip arises on its medial side. These slips are responsible for the roughness at the angles of the ribs.

The Longissimus (thoracis, cervicis and capitis) is inserted into lumbar accessory and transverse processes, and into thoracic transverse processes and nearby parts of the ribs (Th. 2–12). Bundles arising medial to these (Th. 1–4) are relayed to the cervical transverse processes (C. 2–6) as the Longissimus Cervicis. Other bundles arising medial to these again (upper Th. transverse and lower C.

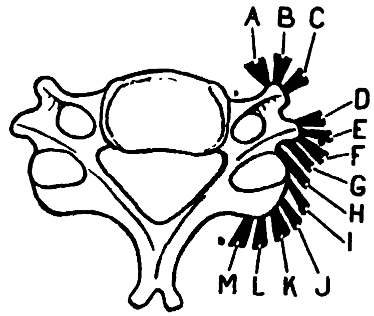


FIG. 637. The muscles attached to the transverse and articular processes of a cervical vertebra. (A) Longus Cervicis. (B) Longus Capitis. (C) Scalenus Anterior. (D) Scalenus Medius. (E) Scalenus Posterior. (F) Levator Scapulae. (G) Splenius Cervicis. (H) Ilio-costo-cervicis. (I) Longissimus Cervicis. (J) Longissimus Capitis. (K) Semispinalis Capitis. (L) Semispinalis Cervicis. (M) Multifidus.

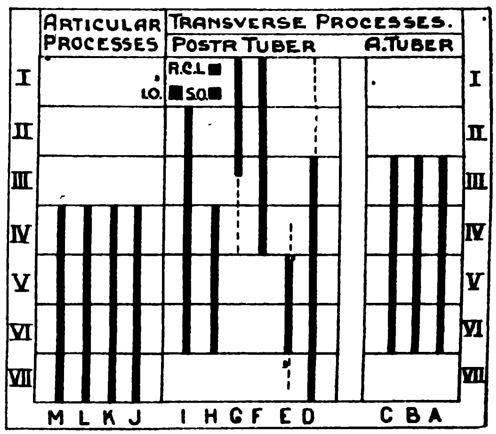


FIG. 638. Graphic representation of figure 637.

articular processes) extend as a broad fleshy band to be attached to the mastoid process deep to the Splenius Capitis and Sterno-mastoid. The Longissimus is the only column of the Sacro-spinalis to reach the skull. It conceals the costo-transverse joints. The lateral branches

of the lower posterior nerve rami pass between it and the Ilio-costalis.

The Spinalis (thoracis) is largely aponeurotic, flat, and half-an-inch wide. It extends from the upper lumbar to the lower cervical spines. Its lateral border is free.

THE OBLIQUE GROUP OF MUSCLES is covered by the Sacro-Spinalis. Its fibers pass obliquely upwards and medially from transverse processes to spines. It is disposed in 3 layers named: (1) *Semispinalis*, (2) *Multifidus*, and (3) *Rotatores*. The superficial layer naturally (a) spans more segments than the intermediate layer, (b) and therefore takes a more vertical course, and (c) arises nearer the tips of the transverse processes and is inserted nearer the tips of the spinous processes. The same characteristics distinguish the intermediate layer from the deep layer.

The superficial layer spans about 5 segments; the intermediate about 3; the deepest connects adjacent segments.

The Semispinalis (thoracis, cervicis, capitis) forms the superficial layer. Its thoracic and cervical parts arise from the thoracic transverse processes (Th 1–10) and pass obliquely upwards and medially across 5 segments to the cervical and upper thoracic spines (C 2 Th. 4); that is to say, it extends to the axis – not to the atlas. *The Semispinalis Capitis* (Complexus) passes from the upper thoracic transverse processes and lower cervical articular processes (C. 4–Th. 5) to the occipital bone between the superior and inferior nuchal lines. The fibers of this massive muscle run nearly perpendicularly. The medial border is free and is separated from its fellow by the ligamentum nuchae.

The Multifidus arises from the dorsal aspect of the sacrum between its spinous and transverse crests, from adjacent ligaments, from the aponeurosis of the overlying Sacro-spinalis, and from all transverse processes up to C. 4 (actually from mamillary processes in the lumbar region, transverse in the thoracic, and articular in the cervical). It spans about 3 segments to be inserted into the lower border of every spinous process (C. 2–L. 5), the tubercle of the atlas excepted.

The Rotatores bridge one interspace. They are small slips that pass from the root of one transverse process to the root of the spinous process or lamina next above. They are best marked in the thoracic region.

OTHER DEEP MUSCLES. The Interspinales and Intertransversales are well developed in the cervical and lumbar regions, and mostly absent from the thoracic region. The Levatores Costarum are confined to the thoracic region. The suboccipital muscles are the deepest layer of muscles above the axis.

Interspinales are well developed median paired muscles. They unite the bifid tubercles of adjacent cervical spinous processes, and adjacent upper and lower borders of the oblong lumbar spinous processes. *Intertransversales* unite adjacent anterior and adjacent posterior tubercles of the cervical transverse processes; the highest Posterior Intertransverse muscle being the Rectus Capitis Lateralis (*p. 698*). In the lumbar region they are well marked. *The Levatores Costarum* are backward extensions of the External Intercostales, and therefore are supplied by anterior nerve rami. Each Levator Costae is triangular and passes from the tip of a transverse process (C. 7–Th. 11) to the upper border of the rib next below, lateral to its tubercle. There are 12 pairs in all. *The suboccipital muscles* are described below.

The Suboccipital Region

Certain spinal muscles—(Semispinalis Cervicis, Multifidus, Rotatores, and Interspinales)—ascend as far as the spine of the axis; others—(Semispinalis Capitis, Splenius Capitis, and Longissimus Capitis)—extending higher, span the atlas to reach the skull, but none stops at the spine of the atlas—it has no spine. Hence, the suboccipital region.

Now, between the axis and the skull are the atlanto-axial and the atlanto-occipital joints. At the lower joints we shake our heads to indicate the negative and disapproval; at the higher we nod indicating the affirmative and approval. The peculiarities of the bones, joints, muscles, nerves, and vessels warrant attention under the title *suboccipital region.*

Appreciate that the suboccipital region lies deep to the apical part of the posterior triangle of the neck (*fig. 630*) and extends on both sides of it. The Semispinalis Capitis forms the immediate covering or lid; and lower is the Splenius. The occipital artery appears from under cover of the Splenius, flits across the apex of the triangle, disappears deep to the Trapezius, and then pierces it in company of the greater occipital nerve, $1\frac{1}{4}''$ infero-lateral to the inion.

Limits of the Region. *Above,* the inferior nuchal line of the occipital bone; *below,* the axis; *laterally,* the mastoid process, the transverse process of the atlas, and the transverse process of the axis; *medially,* the massive spine of the axis and, above and on a deeper plane, the posterior tubercle of the atlas.

Contents of the Region.

Four muscles	2 Oblique 2 Straight
Two nerves	Greater occipital Suboccipital
Two arteries	Vertebral Occipital

Muscles (*fig. 639*). The *Obliquus Capitis Inferior* is thick, fleshy, and rounded. It passes from the spine of the axis obliquely upwards and laterally to the tip of the transverse process of the atlas. It bounds the region inferiorly. The 3 other muscles are flat and triangular. Of these, the *Obliquus Capitis Superior* passes from the tip of the transverse process of the atlas obliquely upwards and medially to be inserted between the two nuchal lines of the occipital bone lateral to the Semispinalis Capitis. It bounds the region laterally. The *Rectus Capitis Posterior Minor* arises from the posterior tubercle of the atlas; the *Rectus Capitis Posterior Major* from the spine of the axis. These two are attached side by side to the occipital bone between the inferior nuchal line and the foramen magnum.

The Minors, curiously are the only two muscles attached to the posterior tubercle of the atlas. Five muscles (all paired), however, radiate from the end of the spine of the axis, namely, Rectus Capitis Posterior Major, Obliquus Capitis Inferior, Multifidus, Semispinalis Cervicis, and Interspinalis.

Nerves and Arteries. Dissection is made difficult by the denseness of the areolar tissue. Begin by tracing a communicating branch from the greater occipital nerve across the Inferior Oblique to the posterior ramus of the suboccipital nerve (C. 1); alternatively, clean the Rectus Capitis Posterior Major, find its nerve and trace it to the *posterior ramus of C. 1.* This ramus supplies the 4 muscles of the region and sends a twig to the muscle covering the region. Having found these, follow the stem of the nerve through the triangle bounded by the Rectus Capitis Posterior Major and the two oblique muscles—called the **suboccipital triangle**—to the upper border

of the posterior arch of the atlas. This requires the point of the knife. The thin *posterior atlanto-occipital membrane*, the homologue of a ligamentum flavum, is seen uniting the posterior arch of the atlas to the margin of the foramen magnum. Find the *vertebral artery* winding behind the superior articular process Oblique and there gives off its descending branch.

ACTIONS OF DEEP MUSCLES AND COMMENTS. The deep dorsal muscles acting together *extend* the vertebral joints, including the lumbo-sacral joint below and the atlanto-occipital joints above; that is, they extend the pelvis, vertebral col-

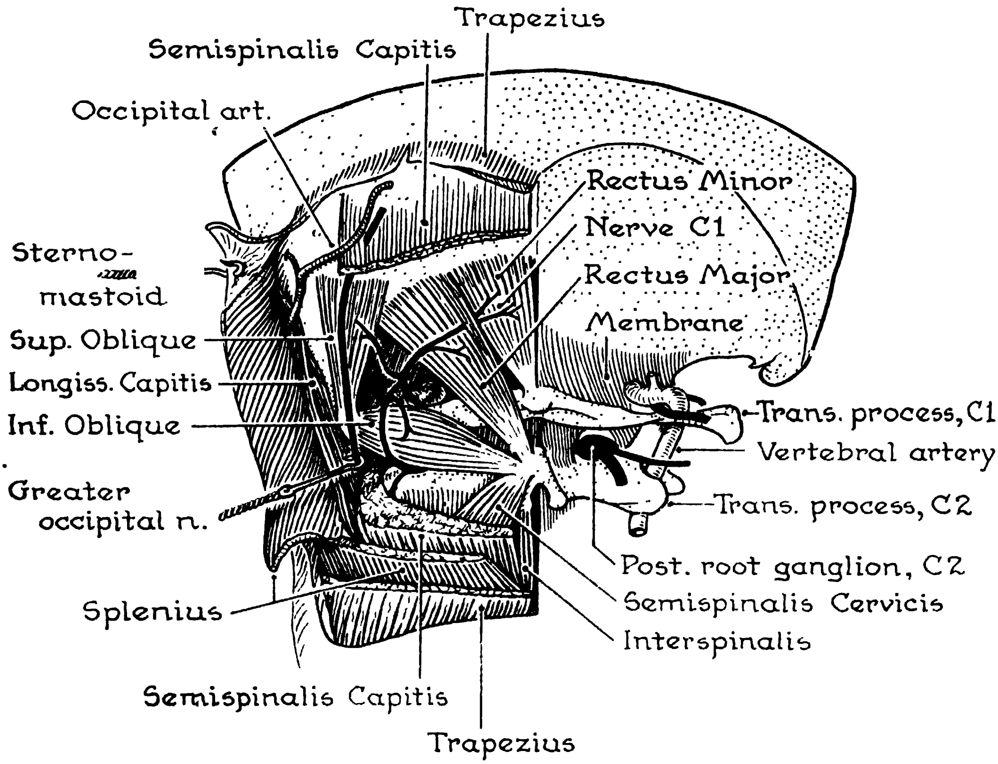


FIG. 639. The suboccipital region.

of the atlas; detach the membrane from the arch and follow the vertebral artery in its groove on the arch to where the posterior ramus of C. 1 emerges between it and the arch. Muscular twigs of the artery pass through the triangle; and commonly a large vein from the vertebral plexus pierces the membrane and passes through the triangle to the *suboccipital plexus of veins*. The *occipital artery* flits across the insertion of the Superior umn, and head. They also prevent, or regulate, *flexion* of these parts, as is the case with the Triceps on the elbow joint. Much, however, of the apparent extensor and flexor movement of the vertebral column takes place actually at the hip joints. When the deep muscles of one side act, *lateral bending* and *rotation* occur, the oblique muscles being the chief rotators (see abdominal muscles p. 209).

Explanatory. It has been seen that the

Semispinalis Cervicis and the Multifidus extend upwards as far as the spine of the axis, and that the Semispinalis Capitis extends beyond this to the occipital bone—but they leave the "spine" of the atlas free. Hence, while you are extending your neck and head, you can rotate your atlas and the head rotates with it. For example, when a noise is heard, the eyes are directed towards the source of the noise, and the head and neck rotate in concert.

Only one muscle, the Rectus Capitis Posterior Minor (paired), is attached to the reduced spine of the atlas, called the *posterior tubercle*, the antagonistic muscle is the Rectus Capitis Anterior (*fig 702*).

The above facts explain why the spine of the axis is downturned and massive—the laminae from which the spine springs are necessarily massive too. They explain why the "spine" of the atlas is upturned and reduced to a tubercle—the posterior arch (laminae) from which the tubercle springs is slender, its function being to prevent spreading of the lateral masses of the atlas. If the atlas had a long spine, extension of the head would be greatly restricted. On the other hand, the atlas has very long transverse processes and, since these are levers, rotation is facilitated.

The Posterior Rami of the Spinal Nerves

General Considerations. It would hardly be expected that the posterior rami of the 31 pairs of spinal nerves would be identical in size, course, relations, and distribution. Yet with the exception of the first two and last two, which require special consideration, they are so similar it is sufficient to give a general description and to note the exceptions to it.

The posterior rami supply a serially segmental territory. They do not extend to the muscles of the limbs, nor are they involved in plexuses. They supply the skin and "native" deep muscles of the back medial to the line of the angles of the ribs. So, they are much smaller than the corresponding anterior nerve rami (save C. 1 and 2) (*fig. 199*). The cutaneous branches commonly trespass beyond the angles of the ribs and a few wander afar, thus; C. 2 (the greater occipital nerve) ascends to the vertex of the skull; Th. 2. extends to the acromion; L. 1, 2, and 3 descend to the buttock. Like the ribs the nerves slope downwards and laterally and they supply a band of skin at a lower level than the intervertebral foramina, where they arise. A given band is overlapped and supplied by the nerve above and the nerve below; so, section of one nerve does not cause anesthesia. Each posterior ramus divides into a medial and a lateral branch (save C. 1, S. 4, 5 and Co. 1). Both branches supply muscles (save L. 5 and Co. 1), and one or the other ends as a cutaneous nerve (save C. 1, C. 6, 7, 8, and L. 4, 5). The branch that becomes cutaneous is, naturally, much larger than the branch that is motor only. Above the midthoracic region the medial branches become cutaneous; below it, the lateral branches. The former become cutaneous near the median plane, the latter several inches from it.

Posterior Root Ganglia. Ganglion C. 1 lies on the posterior arch of the atlas; C. 2 on the lamina of the axis; C. 3-L. 4 in the intervertebral foramina; L. 5-Co. 1 in the vertebral or the sacral canal.

A *typical posterior ramus* takes origin just beyond a posterior root ganglion, which is situated in an intervertebral foramen, and passes backwards on the side of a superior articular process and between two transverse processes. Here

the lateral relation in the cervical and lumbar regions is a Posterior Intertransverse muscle; in the thoracic region, a costo-transverse ligament. The posterior sacral rami emerge from the posterior sacral foramina.

The trunks of nerves C. 1 and 2 are peculiar mainly because the articular processes of the atlanto-occipital and atlanto-axial joints are not the morphological equivalents of succeeding articular processes (*fig. 632*)—they occupy an anterior plane, their joint cavities are homologous with the joint cavities found on each side of a typical cervical intervertebral disc, and they are weight bearing. Hence, trunks C. 1 and 2 pass behind "articular processes". The posterior ramus of C. 1 passes through the suboccipital triangle, supplies the 4 suboccipital muscles, and has no cutaneous branch; the posterior ramus of C. 2 winds round the lower border of the Inferior Oblique and sends its large median branch (greater occipital) through the Semispinalis Capitis and Trapezius to the vertex. Its lateral branch is muscular.

Other Posterior Rami. From C 3 5 the medial branches run medially between the Semispinalis Capitis and Semispinalis Cervicis and pierce the overlying muscles. From C. 6–Th. 6 the medial branches behave similarly after running one layer deeper; that is, between the Semispinalis Cervicis and Multifidus. The lateral branches of the foregoing rami are motor and small. The medial branches of the subsequent rami are motor and small; the lateral branches carry the cutaneous branches and are large. From Th. 7–12 the lateral branches run laterally and deep to the Longissimus, pass between it and the Iliocostalis, and pierce the overlying structures. L. 1, 2, and 3 pass through the Sacrospinalis below the level of cleavage into Longissimus and Ilio costalis, pass to its lateral border, pierce the posterior lamella of the lumbar fascia, cross the iliac crest, and descend to the level of the greater trochanter of the femur. L. 4 and 5 do not become cutaneous.

The Sacral and Coccygeal Nerves. The lower end of the sacrum and the coccyx have, so to speak, been partly dissolved away, leaving the nerve trunks of S. 5 and Co. 1 exposed at the lower end of the sacral canal. The trunk of S. 5 passes through the foramen bounded posteriorly by the sacral and coccygeal cornua (the homologue of an intervertebral foramen) and divides into an anterior and a posterior ramus (*fig. 633*). Trunk Co. 1 divides into an anterior and a posterior ramus on the back of the coccyx. The posterior rami of S. 4, 5 and Co. 1 do not divide into medial and lateral branches, but unite to form a small descending cutaneous nerve that supplies the skin over the coccyx. This nerve is the homologue of the dorsal caudal nerve of the quadruped.

The anterior rami of S. 1–4 enter the pelvis through the anterior sacral foramina (*fig. 326*); those of S. 5 and Co. 1 also require to enter the pelvis where they are joined by a branch from the anterior ramus of S. 4. The ano-coccygeal nerve so-formed supplies the skin at the tip of the coccyx and is the homologue of the ventral caudal nerve of the quadruped. To obtain entrance to the pelvis, S. 5 and Co. 1 pass forwards, one above, the other below the transverse process of the coccyx (i.e., spaces homologous with anterior sacral foramina), pierce structures attached to the side of the sacrum and coccyx (namely, sacro-tuberous and sacro-spinous ligaments and the Coccygeus). After receiving the contribution from S. 4, the ano-coccygeal nerve

descends, pierces the same 3 structures in reverse order to become cutaneous. The dorsal and ventral caudal nerves supply no muscles but are sensory to the circular area of skin on which one rests when seated (*figs. 528*).

Arteries of the Back. 1. THE VERTEBRAL ARTERY is a branch of the subclavian (*fig. 679*). It can be exposed in the suboccipital triangle. On leaving the foramen transversarium of the atlas medial to the Rectus Capitis Lateralis (which is an enlarged posterior intertransverse muscle), it winds backwards round the superior articular process of the atlas, passes in front of the lateral margin of the posterior atlanto-occipital membrane and in so-doing enters the vertebral canal. It occupies the long groove on the posterior arch of the atlas. The posterior ramus of nerve C. 1 passes between it and the arch. It sends twigs to accompany this nerve.

2. BRANCHES OF THE VERTEBRAL, INTERCOSTAL, LUMBAR, AND LATERAL SACRAL ARTERIES accompany the posterior rami of the cervical, thoracic, lumbar, and sacral nerves.

3. THE OCCIPITAL ARTERY is a branch of the external carotid (*fig. 670*). To expose it in its entirety the mastoid process and attached muscles (Sterno-mastoid, Splenius Capitis, Longissimus Capitis, and Digastric) require to be removed. It is then seen to follow the posterior belly of the Digastric across the internal carotid artery, XII, X, and XI nerves, and internal jugular vein, and then to cross the Rectus Capitis Lateralis, Obliquus Capitis Superior, and the apex of the posterior triangle of the neck, where it lies on the Semispinalis Capitis with the greater occipital nerve; then it pierces the Trapezius and ascends in the scalp to the vertex of the skull. In its course it occupies a groove on the mastoid bone.

Branches of the Occipital Artery. Muscular branches, including the sterno-mastoid branch in the anterior triangle of the neck; *meningeal twigs* which traverse the jugular, mastoid, and parietal foramina; a *descending branch* which splits near the lateral border of the Semispinalis Capitis into two, a superficial and a deep branch, which pass to the two surfaces of the muscle. The superficial branch anastomoses with the transverse cervical artery; the deep branch anastomoses with the profunda cervicis artery.

4. THE PROFUNDA CERVICIS ARTERY is one of the two terminal branches of the costo-cervical trunk. It enters the back by passing between the neck of the 1st rib and the transverse process of the 7th cervical vertebra. It ascends deep to the Semispinalis Capitis and anastomoses with the descending branch of the occipital a. and with branches of the vertebral a. This becomes a collateral circulation when the carotid a. is ligated.

THE VEINS form large thin walled plexuses which tend to follow the arteries. In the neck they mainly descend around the vertebral and profunda cervicis arteries and end as correspondingly named veins. The profunda cervicis vein ends in the vertebral vein which in turn ends in the innominate vein. Sometimes a vein accompanies the occipital a. and ends in the internal jugular vein.

The Veins of the Vertebral Column. (The Vertebral Venous System.)

The vertebral canal contains a dense plexus of thin-walled, valveless veins which surround like a basket-work both the dura mater of the spinal cord and the posterior longitudinal ligament. Above, this plexus communicates through the foramen magnum with the occipital and basilar sinuses of the cranium. Anterior and posterior longitudinal channels,

called the anterior and posterior *longitudinal venous sinuses*, can be discerned in this plexus (*fig. 640*). At each spinal segment the plexus receives veins which leave the spinal cord with the spinal nerve roots and a vein, the *basivertebral vein*, from the body of the vertebra; and in turn it is drained by intervertebral veins which pass through the intervertebral and anterior sacral foramina to the vertebral, intercostal, lumbar, and lateral sacral veins. Through the body of each

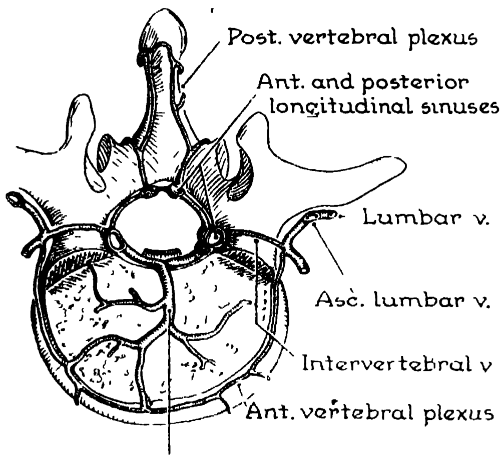


FIG. 640. The veins of the vertebral column

vertebra come veins which form a meagre *anterior vertebral plexus*, and through the ligamenta flava pass veins which form a well marked *posterior vertebral plexus*. In the cervical region, these plexuses communicate freely with the occipital and profunda cervicis veins which receive the mastoid and posterior condylar emissary veins from the sigmoid sinus; in the thoracic, lumbar, and pelvic regions the azygos (or hemiazygos), the ascending lumbar, and the lateral sacral veins respectively further link segment to segment.

The *ascending lumbar vein* is an anastomotic vein that ascends in front of the lumbar transverse processes linking one lumbar vein to another. Below, it communicates with the iliolumbar and common iliac veins and above it communicates with the azygos (or hemiazygos) vein.

HISTORICAL. Batson recently injected a thick radio-opaque solution into the central end of the deep dorsal vein of the penis of an adult cadaver. Under the fluoroscope he watched the fluid enter and pass through the prostatic plexus of veins and flow onwards through the internal and common iliac veins of both sides to the inferior vena cava. Stereoscopic films showed that the lateral sacral veins were filled and that the fluid had entered the sacral and iliac bones. He noted the resemblance between this venous pattern and that of an early spreading carcinoma of the prostate.

Into another cadaver he injected a thinner solution in order to fill finer veins. Strangely, none of the solution entered the inferior vena cava, but it entered the sacrum and ilium and the veins of the lower lumbar spine.

Into subsequent cadavera he injected larger quantities (200 cc.) of thin solution and found that it progressed up the spine and entered the venous sinuses and veins of the cranial cavity—but it always by-passed the caval veins.

Into the deep dorsal vein of an anaesthetised monkey he injected radio-opaque colloidal thorium. This was observed to pass into the i. v. cava; but, when a towel was tied around the monkey's abdomen in order to increase the intra-abdominal pressure and the injection repeated, some thorium passed for a short way into the i. v. cava but most passed into the vertebral system of veins and could be followed in radiograms past the zone of compression into the veins of the thoracic spine and out into the lower

intercostal veins. A second experiment gave identical results, thereby demonstrating that the injections in the cadavera were not artifacts.

He injected a thin solution into a venule of an adult female breast and found that the fluid spread into the clavicles, head of the humerus, cervical vertebrae, intercostal and azygos veins, and into the transverse and sagittal venous sinuses of the skull. Here again the pattern was comparable to the metastatic spread in carcinoma of the breast.

These findings have led Batson to add to the recognized pulmonary, portal, and caval venous systems a fourth or **vertebral venous system.** This system may be considered a separate, although overlapping system of veins. It comprises the veins of the brain, skull, neck, viscera, vertebral column (and their valveless connections in the limb girdles), and the veins of the body wall.

Clinical Significance. The foregoing experiments indicate (1) that compression of the thorax and abdomen with the larynx and other sphincters closed as occurs in straining, coughing, and lifting with the upper limbs, not only prevents blood from entering the thoraco-abdominal veins but squeezes it out of them into the vertebral system; (2) that the increase in the intraspinal and intracranial pressure that occurs during coughing, sneezing, and straining is active not passive; (3) that tumours and abscesses having connection with this venous system may have metastases anywhere along this system without involving the portal, pulmonary, or caval systems; and (4) that the cranial and spinal parts of the system, as well as being pathways, are blood depots or storage lakes of blood; further, (5) they reveal the channels through which blood from the lower limbs and pelvis may in favourable circumstances return to the heart after the i. v. cava has been obstructed below the renal veins.

CHAPTER 21

THE CONTENTS OF THE CRANIUM

The Skull Cap.

To remove the skull cap, the scalp and epicranial aponeurosis should be incised coronally from a point an inch above one zygomatic arch to a corresponding point above the opposite arch. The anterior half of the scalp should then be pulled well down over the face and the posterior half well down over nuchal region; the temporal fascia and muscle should be scraped downwards. A piece of string passed around the skull, less than an inch above the superciliary arches and inion, and pulled tight, enables an encircling pencil mark to be made on the bone as a guide to the saw-cut.

STRUCTURE. The bones of the roof of the skull have an outer and an inner, table with a vascular, marrow space, called the *diploe*, sandwiched in between Injuries to the roof of the skull compress the inner table and tend to cause it to splinter like glass; hence, it has been called the *vitreous layer*. In the child the bone consists of a single layer. Into this layer veins grow, branch, rebranch, and unite with neighboring veins; and marrow is laid down around them. Thus is the diploe formed and with it the outer and inner tables. Diploe does not form in the bones covered with thick, fleshy muscles: (a) the squama temporalis and (b) the nuchal part of the occipital. In these parts the bone remains "infantile"—thin and translucent. Hollow buds of mucous membrane sprout from the nasal cavity and tympanic antrum into the diploic layer of certain bones and, by replacing it, form *air sinuses*. These three types of bone are revealed to you on the sawn surface of the skull: (1) undifferentiated non-diploic bone in the squama of the temporal bone, (2) air sinuses in the frontal bone, and (3) diploic bone elsewhere. Usually there are 4 *diploic veins* on each side and of these the most important clinically is the frontal diploic vein (*fig. 641*). It emerges through an obvious, though small, orifice in the supra-orbital notch and joins the supra-orbital vein. The anterior temporal diploic vein passes through the great wing of the sphenoid to the sphenoparietal blood sinus; the posterior temporal diploic vein emerges through the postero-inferior angle of the parietal bone and joins the transverse sinus; and the occipital diploic vein emerges near the internal occipital protuberance and ends in the transverse sinus; but all sometimes open into surface veins. There are no accompanying diploic arteries; the meningeal and pericranial arteries provide the arterial blood.

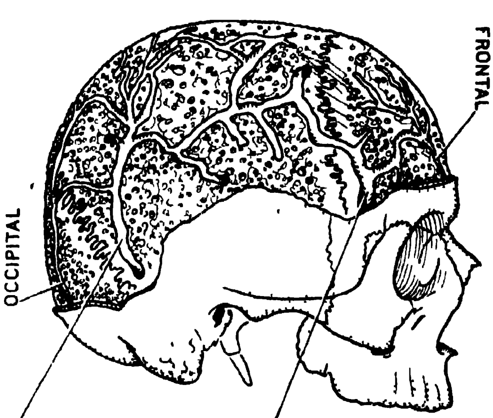


FIG. 641. The four diploic veins.

The Meninges. Three meninges or membranes envelop the brain. They are the *dura mater*, *arachnoid mater*, and *pia*

mater. Their names indicate their qualities: the dura is tough, the arachnoid is like a spider's web, and the pia clings faithfully to the brain surface like a skin, following all its irregularities. Between the dura mater and arachnoid mater there is a potential space, the *subdural space.* Between the arachnoid mater and pia mater there is an actual space, the *subarachnoid space,* filled with cerebro-spinal fluid. The arachnoid mater is attached to the pia mater by loose scattered threads. As the arachnoid does not dip into the sulci of the brain, but bridges them, innumerable small and several large *cisterns* filled with cerebro-spinal fluid are seen in the carefully removed brain. The cerebral arteries travel in the subarachnoid space.

THE DURA MATER consists of two closely adherent fibrous layers—an outer and an inner. The *outer layer* or endocranium is a periosteum. It is continuous through the foramina of the skull with the external periosteum or pericranium. Its outer surface is rough and shaggy (from vessels and fibers withdrawn from the bone). In the parietal region particularly two structures stand out from it in relief: (1) Bulging cauliflower-like masses, *arachnoid granulations,* covered with a film of dura, grow widely (nearly 1″) from each side of the median sagittal plane. They are responsible for the marked pits on the parietal bone. (2) Branches of the *meningeal vessels* run in the outer layer of the dura and make grooves on the bones, notably the parietal bone.

The *inner layer of the dura* is lined with endothelial cells and is smooth like a serous membrane. It is reduplicated to form 4 inwardly projecting folds, which partially subdivide the cranial cavity into compartments, and being taut they prevent shifting of the cranial cargo, which is the brain. Two of the reduplicated folds, the *falx cerebri* and *falx cerebelli,* are sickle-shaped occupants of the median sagittal plane. The other two, the *tentorium cerebelli* and the *diaphragma sellae,* form roofs for the cerebellum and hypophysis cerebri respectively. Between the layers of the dura mater there are certain spaces and canals lined with endothelium, filled with blood, and continuous with veins. They are called *venous sinuses,* and are described below.

The Falx Cerebri is sickle-shaped. Its apex is attached to the crista galli. Its convex upper border extends from the crista galli to the internal occipital protuberance. It finds attachment to the internal frontal crest, and to the lips of the sagittally placed sulcus on the frontal, parietal, and occipital bones. Its lower border suspends the tentorium cerebelli behind and projects free between the cerebral hemispheres in front. It does not descend to the body of the corpus callosum; but in cadavera that have lain on their backs a notch made by the falx is often seen on the splenium of the corpus callosum. Its anterior part may be cribriform. The superior sagittal venous sinus occupies its attached upper border; the inferior sagittal venous sinus occupies the free part of its lower border, and the straight venous sinus the attached part of its lower border.

The Falx Cerebelli is a slight fold attached to the internal occipital crest and to the tentorium. Its anterior border is free and is often bifid below. It projects between the hinder parts of the cerebellar hemispheres. The occipital sinus lies in its attached posterior border.

The Tentorium Cerebelli, shaped like a bell-tent with open flaps, forms a roof for the cerebellum and a floor for the occipital lobes and hinder parts of the

temporal lobes of the cerebrum. Its *peripheral border* is attached on each side to the posterior clinoid process (which it drags laterally, downwards, and backwards) and to the lips of the groove on the superior border of the petrous bone, postero-inferior angle of the parietal bone, transverse groove on the occipital bone, and to the internal occipital protuberance. Its *medial border* is free and tentorium is held taut by the falx cerebri (and falx cerebelli), the line of union being occupied by the straight sinus. Its attached border is occupied on each side by the superior petrosal and transverse sinuses

The Diaphragma Sellae forms a "tentorium" for the hypophysis cerebri and it has a large central aperture for the stalk of the hypophysis cerebri. Pia is re-

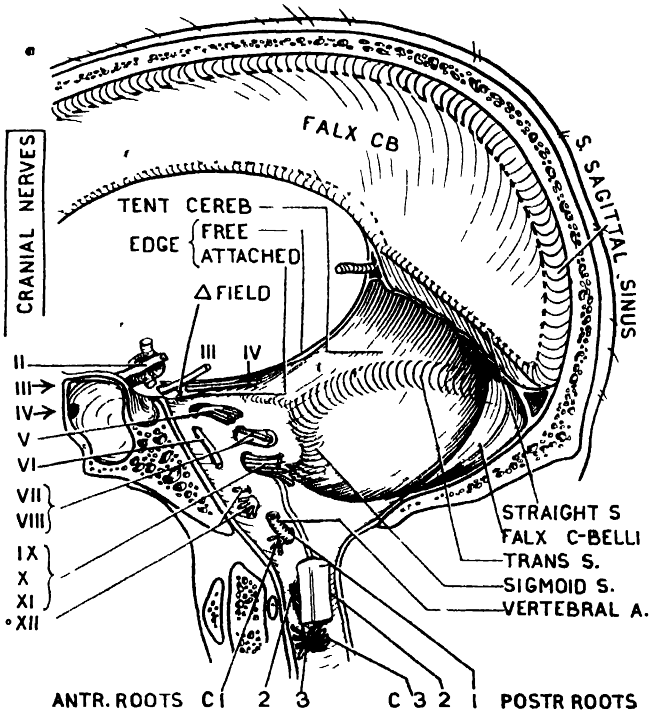


FIG. 642 The tentorium cerebelli and the nerves piercing the dura mater

it bounds an oval opening (incisura tentorii) and closely grips the sides of the midbrain. It is fixed in front to the anterior clinoid process, which it drags backwards into a cone. To reach the anterior clinoid process, the medial free border crosses above the anterior end of the peripheral border, and with it forms a *triangular field* at the side of the diaphragma sellae (*figs. 642, 644*). In the triangle run nerves III and IV. The flected from the stalk to the margin of the aperture, thereby closing it. But with advancing age the pia and the subarachnoid space may descend to form a circular moat around the gland (cf., the circumvallate papillae of the tongue). (Sunderland.)

The Cerebro-spinal Fluid (C. S. F.) is secreted by the chorioid plexuses of *the lateral, third, and fourth ventricles* of the brain. It escapes through three

orifices in the fourth ventricle into the subarachnoid cisterna magna. The fluid diffuses over and around the brain and spinal cord (medulla) and, though the spinal cord ends at the 2nd lumbar vertebra, the sub-arachnoid space with its contained fluid extends to the 2nd sacral vertebra (*fig. 42, p. 44*). The C. S. F. seeps into the tissues of the brain and cord perivascularly. It returns to the blood stream via the arachnoid granulations.

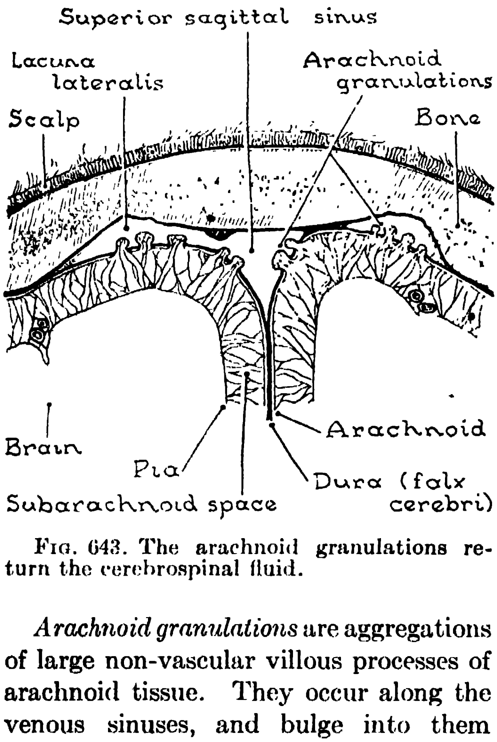


FIG. 643. The arachnoid granulations return the cerebrospinal fluid.

Arachnoid granulations are aggregations of large non-vascular villous processes of arachnoid tissue. They occur along the venous sinuses, and bulge into them through the inner layer of dura (*fig. 643*). Small and villous in youth; large and cauliflower-like in the aged; they are most conveniently seen when the superior sagittal sinus is opened.

The Venous Sinuses of the Dura Mater may be classified thus:

1. The unpaired median sagittal sinuses and their continuations: (a) the superior sagittal and right lateral; (b) the inferior sagittal, straight, and left lateral; and (c) the occipital.

2. Those associated with the paired cavernous sinuses: cavernous, sphenoparietal, superior petrosal, inferior petrosal; intercavernous and basilar.

The blood sinuses have no valves. They lie between the outer and inner layers of the dura, except the inferior sagittal and straight sinuses which lie within a reduplication of the inner layer. The superior sagittal, lateral, petrosal, and occipital sinuses groove the bones on which they lie. Their tributaries mostly come from the neighboring parts of the brain; the middle meningeal veins partly end in the superior sagittal sinus; three of the four diploic veins of each side commonly end in the sinuses. All sinuses drain ultimately into the internal jugular veins. Accessory veins, called *emissary veins*, connect the sinuses with the extracranial veins.

The superior sagittal sinus (unpaired) begins at the foramen cecum between the frontal and ethmoidal bones. It occupies the entire length of the attached margin of the falx cerebri, and at the internal occipital protuberance it becomes the right lateral sinus. Six or so cerebral veins enter it, against the blood stream, and large meningeal veins join it. It increases in size from before backwards; it is triangular in section; fibrous strands cross its lumen. Arachnoid granulations bulge into its lateral expansions, called *lacunae laterales*.

The inferior sagittal sinus (unpaired) is very small. It occupies the free edge of the falx cerebri. (It receives adjacent cerebral veins.) On being joined by the *great cerebral vein* of Galen, which turns upwards behind the splenium of the corpus callosum to join it, it becomes the straight sinus.

The straight sinus (unpaired) lies in the

line of union between the tentorium cerebelli and the falx cerebri, and therefore though straight it is not horizontal. At the internal occipital protuberance it becomes the left lateral sinus. (It receives some veins from the adjacent parts of the cerebellum and occipital lobes.)

The lateral sinuses (paired) are the continuations of the superior sagittal sinus, which usually turns to the right, and of the straight sinus, which usually turns to the left. Each lateral sinus has 2 parts—a transverse and a sigmoid.

The transverse sinus occupies the attached margin of the tentorium cerebelli and grooves the occipital bone and postero-inferior angle of the parietal bone. It is triangular on section. Leaving the tentorium it becomes the *sigmoid sinus* which takes a sigmoid course downwards in the angle between the mastoid and petrous bones, and returning to the occipital bone passes forwards and then downwards over the jugular process and through the jugular foramen to become the internal jugular vein. It is semilunar on section. The transverse sinus is joined by the superior petrosal sinus, the inferior anastomotic vein from the cerebral hemisphere, two diploic veins, and adjacent cerebral and cerebellar veins.

The confluens sinuum is the dilatation commonly found at the beginning of the right transverse sinus. It may cause a depression (torcular Herophili) on the occipital bone beside the internal occipital protuberance. Here the right and left transverse sinuses communicate, usually widely; and here the occipital sinus begins.

The occipital sinus is extremely variable in size. It descends in the attached margin of the falx cerebelli, bifurcates, and after partly encircling the foramen magnum ends in the sigmoid sinuses. (It communicates with the vertebral venous plexus (*fig. 640*).)

The cavernous sinus (paired) is a trabeculated and expanded sinus lying at the side of the hypophyseal fossa and of the hollow body of the sphenoid and extending laterally to the trigeminal ganglion and to the maxillary nerve. The internal carotid artery and cranial nerves III, IV, V^1, and VI, and sympathetic fibers are within its walls. It receives the superior and inferior ophthalmic veins (they have no valves), the superficial middle cerebral vein, and the sphenoparietal sinus. It is drained by the superior and inferior petrosal sinuses.

The sphenoparietal sinus, (paired) lying underneath the lesser wing of the sphenoid, connects the anterior branch of the middle meningeal vein and the anterior temporal diploic vein to the cavernous sinus.

The superior petrosal sinus (paired) occupies the groove on the superior border of the petrous bone in the attached margin of the tentorium. It drains the cavernous sinus into the transverse sinus. At its origin it bridges, like an aqueduct, the root of the trigeminal nerve, though it may pass below it.

The inferior petrosal sinus (paired) is much larger than the superior. It occupies the groove dorsal to the suture between the basi-occipital and petrous bones, passes through the anterior compartment of the jugular foramen, and ends in the internal jugular vein ½″ below the skull. It drains the cavernous sinus. The abducent nerve perforates it. It receives the internal auditory vein and local veins.

The intercavernous sinus connects the cavernous sinuses of opposite sides around and below the hypophysis cerebri.

The basilar sinus is a wide trabecu-

basi-occipital. It unites the cavernous and the inferior petrosal sinuses of opposite sides and communicates below with the vertebral venous plexus (*fig. 640*).

Emissary Veins. All the dural sinuses ultimately deliver their blood to the lateral sinuses and so to the internal jugular veins, with the exception of the inferior petrosal sinuses which join the internal jugular veins directly. Certain veins, called emissary veins, pass through the foramina of the skull and connect the sinuses inside with the veins outside.

Emissary veins pass from the undermentioned sinuses to the exterior: *Superior sagittal sinus:* (1) via the unpaired foramen cecum, which lies between the ethmoidal and frontal bones, to the veins of the nose. Present in the child, it seldom persists in the adult. (2) via the parietal foramina (paired) to the veins of the scalp. *Sigmoid sinuses:* (3) via the mastoid foramen to the posterior auricular vein. This, the mastoid emissary vein, is the largest of these veins and is fairly constant. (4) via the condylar foramen which opens behind the occipital condyle to the suboccipital veins. This is often large but is inconstant. *Cavernous sinuses:* (5) as there are no valves in the ophthalmic veins the blood by reverse flow can pass from the cavernous sinuses to the supra-orbital, facial, and other veins. (6) via the foramen ovale and foramen Vesalii (when present) to the pterygoid plexus. (7) via the carotid canal (and foramen lacerum?) to the pharyngeal plexus. *The occipital and basilar sinuses:* (8) communicate with the veins of the vertebral venous plexus.

Removal of the Brain.

Incise the dura along each side of the superior sagittal sinus, keeping an inch from the median plane so as to avoid the lacunae laterales and arachnoid granulations. Incise the two side portions of the dura coronally from the vertex towards the ear, and turn down the four flaps thus formed. Sever the falx and the contained sagittal sinuses just above the crista galli. Withdraw the falx cerebri from between the cerebral hemispheres, and as you do so note and cut the 5 or 6 large cerebral veins which open into the superior sagittal sinus against the blood stream.

It is fortunate that the brain, floating in cerebrospinal fluid and encased in its three membranes, has the monopoly of the cranial cavity. Not even fat is permitted within; the brain has no rival for space. This total absence of fat within the cranial cavity makes simple the work of the dissector. Proceed to identify and examine the nerves and vessels as instructed below, and for purposes of subsequent study, cut them long on one side and short on the other, using scissors—a knife would tear the nerves which are delicate because they have not yet acquired an epineural sheath from the dura mater.

Let the head fall back, and gently raise the frontal lobes of the brain. On the floor of the anterior cranial fossa, about half a centimetre from the median plane, observe a long (3 cm.), fragile stalk with a slightly enlarged anterior end, the *olfactory tract* and *bulb* (*fig. 644*). The bulb is fixed to the floor by delicate *olfactory nerves* which descend from it and, in tubes of arachnoid mater, pierce the cribriform plate to supply a small area on the roof and walls of the nasal cavity. Cut one *olfactory tract* far back and so leave the olfactory bulb resting on the cribriform plate; on the other side raise the olfactory tract and bulb with the frontal lobe. Observe the *optic chiasma* lying well behind the optic (chiasmatic) groove, and the *optic nerve* passing on each side to the optic foramen. Cut one nerve long, the other short. The *internal carotid artery* ascends in the angle between

the optic tract and optic nerve. Cut it. Cut the stalk of the *hypophysis cerebri* (pituitary gland) behind the optic chiasma and above the diaphragma sellae.

Ease the temporal pole from under cover of the lesser wing of the sphenoid first on one side then on the other, turning the head from side to side, taking advantage of gravity, and all the time supporting the brain with the palm. With a knife cut through the upper part of the will be cut in the median plane behind. The *oculo-motor nerve* (N. III) is large. It enters a cul-de-sac in the triangular field between the attachments of the tentorium to the anterior and posterior clinoid processes. Trace it backwards and medially, past the posterior clinoid process and between the posterior cerebral artery above and superior cerebellar artery below, to the front of the midbrain just above the pons. Cut it. The

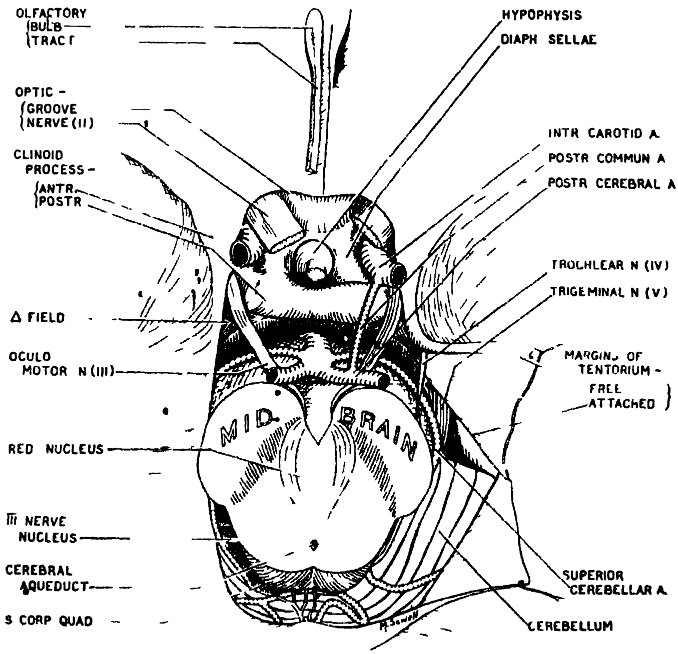


FIG 644 A stage in the removal of the brain.

midbrain and let the forebrain fall away in your hand. For success in this last procedure the bell-tent shape of the tentorium cerebelli must be borne in mind, the blade kept above the clinoid processes and free margin of the tentorium, and the cut in the midbrain made to rise posteriorly.

On each side the *posterior cerebral artery* will be cut through where it winds around the midbrain, and the *great cerebral vein* *trochlear nerve* (N. IV), the most delicate of the cranial nerves, pierces the dura in the same triangle as nerve III, but farther back, and it passes between the same two arteries. Follow it backwards around the midbrain under shelter of the free edge of the tentorium, which requires to be raised to bring it into view. Cut it. Sever the attached margin of the tentorium cerebelli on both sides, but leave it attached behind at the internal occipital

Protuberance. On raising the flaps thus formed, the cerebellum is exposed.

Identify the *trigeminal nerve* (N. V.), the largest of the cranial nerves, where it arches over the most medial part of the upper border of the petrous bone below the attached margin of the tentorium. Follow it as it curves backwards and slightly downwards to the side of the pons. Cut it. With the handle of the knife hold the midbrain and pons back from the basi-occipital and looking down identify the *abducent nerve* (N. VI). It arises at the lower border of the pons (between the pyramid and olive) in line with N. III, ascends clamped to the pons by the anterior inferior cerebellar artery, and pierces the dura over the inferior petrosal sinus. Cut it.

The *facial* (N. VII) and *auditory* (N. VIII) *nerves* with the *nervus intermedius* between them arise at the lower border of the pons, abreast of N. VI and almost in line with N. V. They pass laterally and slightly upwards into the internal auditory canal. The *internal auditory artery*, a branch of the anterior inferior cerebellar, accompanies them, and the *internal auditory vein* ends in the i. petrosal sinus. Cut them.

The *glosso-pharyngeal* (N. IX), *vagus* (N. X), and *accessory* (N. XI) *nerves* arise from the medulla and spinal cord behind the olive, just below and in line with the nn. VII and VIII. They pass laterally across the tuberculum jugulare, pierce the dura mater half-an-inch below the internal auditory meatus, and enter the jugular foramen between the inferior petrosal and sigmoid sinuses. Nerve IX runs horizontally and pierces the dura independently in front of nn. X and XI. The root fila of nn. X and XI ascend with increasing degrees of obliquity and pierce together. Nerve XI grooves the tuberculum jugulare.

The *hypoglossal nerve* (N. XII) arises from the medulla between the pyramid and olive in line with the origin of nerves III and VI above and with the anterior root of the first cervical nerve below. Its root fila, like those of the anterior or motor root of a spinal nerve, converge laterally, and they pierce the dura through two apertures, and enter the anterior condylar (hypoglossal) canal. Cut them.

With a long scalpel inserted through the foramen magnum cut across the spinal cord (medulla) with one sweep. With it the vertebral artery and the spinal root of the accessory nerve on each side will be severed Remove the midbrain and the hindbrain (i.e., pons, medulla, and cerebellum). Observe the groove on the cerebellum caused by the margin of the foramen magnum. This no doubt is not present during life when the brain floats in cerebro-spinal fluid.

The Great Arteries and Their Relations to the Cranial Nerves. The brain is supplied by two paired arteries only, the *internal carotid* and the *vertebral*. These and their branches are the only arteries found within (i.e., internal to) the dura mater of the cranium. The meningeal arteries, it is true, lie within the cranium, but being periosteal arteries, they run in the outer or periosteal layer of the dura, and supply only it and the adjacent bone.

The Internal Carotid Artery pierces the dura medial to the anterior clinoid process, which it grooves. It at once gives off the *ophthalmic a.* which runs below the optic nerve through the optic foramen, and the *posterior communicating a.* which runs backwards, medial to N. III. It then ascends in the angle between the optic nerve and tract, and ends as the *anterior* and *middle cerebral aa.*: of these, the anterior cerebral a. runs medially above the optic

nerve; the middle cerebral a. runs laterally in the stem of the lateral cerebral fissure (of Sylvius).

THE VERTEBRAL ARTERY pierces the dura behind the occipital condyle and grooves the margin of the foramen magnum. Here it lies abreast of the interval between the last cranial and the first cervical nerve. It passes forwards and upwards round the medulla, between these two nerves, and in front of the former (hypoglossal nerve) to the lower border of the pons where it unites with its fellow to form the basilar a. *The posterior inferior cerebellar a.* is the largest branch of the vertebral a. It arises at a variable level and bears a variable relationship to IX, X, XI nerves. To reach the cerebellum it usually descends in front of these nerves and crosses below them, but it may pass between X and XI, it may form a large loop over the nerves, and it may cross immediately above IX.

The basilar artery ascends medianly from the lower border of the pons to the upper border where it ends in a T-shaped bifurcation, the *right* and *left posterior cerebral aa.* In front of it are the basi-occipital, basisphenoid and dorsum sellae. Three large paired branches proceed horizontally from it namely: (1) the *anterior inferior cerebellar a.*, which arises near the lower border of the pons, clamps N. VI to the pons, runs tortuously above, below, or between nerves VII and VIII, and sends the *internal auditory a.* to the inner ear; (2) the *superior cerebellar a.*, and (3) the *posterior cerebral a.* which have nn. III and IV running between them.

"In some positions of these arteries they lie in the way of the surgeon proceeding to reach the roots of the fifth, eighth or ninth nerves and add danger and difficulty to the operation The arteries may also cause pressure upon the nerves and interfere with their functions" (Watt).

Meningeal Vessels and Nerves. MENINGEAL ARTERIES are periosteal arteries. Hence, they lie in the outer layer of the dura mater, anastomose with each other, and supply—the dura mater, the inner table of the skull, and the diploe. The *middle meningeal a.*, assisted by a branch of the *anterior ethmoidal a.* in the anterior cranial fossa, caters for the territory above the level of the tentorium cerebelli. Twigs from other arteries make small contributions, thus: from the posterior ethmoidal a. in the anterior fossa; from the accessory meningeal and internal carotid aa. in the middle fossa; from the occipital a. (via the jugular and mastoid foramina), the ascending pharyngeal a. (via the jugular foramen and anterior condylar canal), and the vertebral a. in the posterior fossa. A twig from the occipital a. passes through the parietal foramen. The middle meningeal and lacrimal aa. anastomose (*fig. 661*).

MENINGEAL VEINS accompany the arteries and communicate with the venous sinuses and with the diploe.

MENINGEAL NERVES. Numerous nerve fibres accompany the vessels in the pia and arachnoid; it is claimed that these arise from most of the cranial nerves, but whether they are efferent or afferent is not known. The fibres reaching the dura have a more restricted origin; they have been identified as arising from the trigeminal (V), facial (VII), vagus (X), and hypoglossal (XII) nerves. The dura of the anterior and middle cranial fossae and the tentorium cerebelli are supplied thus: V^1 supplies the tentorium and its ethmoidal branch (probably) supplies the anterior fossa; twigs of V^2 are distributed with the branches of the middle meningeal artery; V^3 sends a recurrent twig through the foramen spinosum to

the middle fossa; and there is evidence that twigs of the superficial petrosal nerves, having cell bodies in the facial (geniculate) ganglion, also supply the middle fossa. The dura of the posterior cranial fossa receives a recurrent branch from X through the jugular foramen, and from XII (probably derived from C. 1 or 2) through the anterior condylar canal.

crests, a median and two lateral, which are separated from each other by two prominent backwardly projecting tubercles, the *anterior clinoid processes*. The median concave crest connects the anterior clinoid processes of opposite sides above the *optic foramina* and across the body of the sphenoid. Each lateral concave crest curves from the anterior

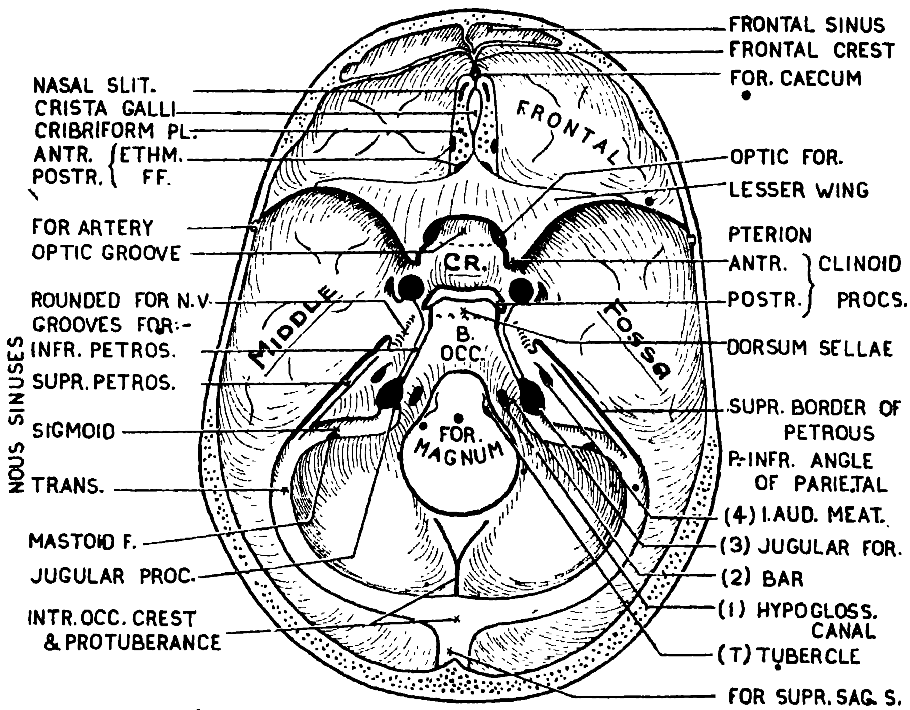


FIG. 645 The interior of the base of the skull. Note features 1, 2, 3, 4 on the coronal plane of the tubercle for the check ligament (*see p. 625*).

THE INTERIOR OF THE BASE OF THE SKULL

The Boundaries of the Fossae (*fig. 645*). The interior of the base of the skull has three terraces called fossae—an *anterior*, a *middle*, and a *posterior*. The anterior cranial fossa is on a higher plane than the middle fossa, and the middle fossa than the posterior. The anterior cranial fossa is sharply marked off from the middle fossa by three free concave

clinoid process laterally towards the sharp antero-inferior angle of the parietal bone (pterion), but fails to reach it. It is formed by the *lesser wing of the sphenoid*, and it overhangs the front of the middle fossa. Medianly, the middle cranial fossa is marked off from the posterior cranial fossa by a rectangular plate, the *dorsum sellae*, at whose upper angles are tubercles, the *posterior clinoid processes*. On each side, it is marked off

by the *superior border of the petrous bone.* This border extends from the body of the sphenoid, slightly below the side of the dorsum sellae, horizontally laterally and backwards towards the blunt postero-inferior angle of the parietal bone—actually to a point about a finger's breadth behind the external auditory meatus and some distance in front of the blunt angle. The medial ¾ inch of the superior border of the petrous bone is crossed by the roots of nerve V and, so, is rounded; elsewhere it has a shallow groove for the superior petrosal sinus, bounded by two lines which give attachment to the tentorium cerebelli.

NOTE ON THE LESSER WING OF THE SPHENOID. Each lesser wing is triangular Its attenuated *apex* reaches nearly to the pterion Its base is attached to the body of the sphenoid by *two flat roots*, an anterior and a posterior, which embrace the optic nerve and ophthalmic artery, thereby forming the *optic foramen.* During the first year the anterior roots meet and fuse above the anterior part of the body, thereby forming a yoke, the *jugum sphenoidale* (*fig. 646*). The posterior edge of the jugum is the anterior edge of the *optic* (*chiasmatic*) *groove.*

The posterior root may fail to develop; the optic foramen then remains part of the superior orbital fissure. The *anterior clinoid process* is drawn by the tentorium postero-medially. Below it and also medial to it lies the internal carotid artery, which grooves it. The *posterior edge* of the lesser wing is concave, free, and fits into the stem of the lateral cerebral fissure of the brain. The *anterior edge* articulates with the orbital plate of the frontal bone.

The Anterior Cranial Fossa. The upward continuation of the nasal septum, called fancifully the *crista galli* or cock's comb, rises from the anterior half of the anterior fossa in the median plane. It is part of the ethmoid bone (ethmos, Gk. = a sieve). The crista extends backwards to the sphenoid and forwards to an interosseous canal placed between the ethmoid and frontal bones. In early life, the superior sagittal sinus communicates with the veins of the nose through this canal; in adult life, the canal is usually closed; hence, it is called the *foramen cecum.* Ascending in front of the foramen cecum is a ridge on the frontal bone, the *frontal crest.* The crista galli and the frontal crest give attachment to the falx cerebri. For 3 mm. on each side of the crista galli the floor of the anterior

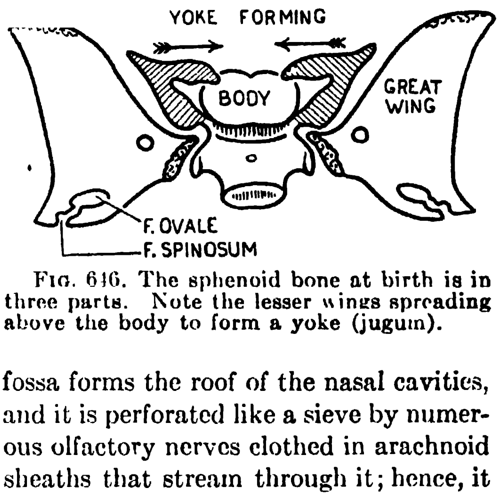


FIG. 646. The sphenoid bone at birth is in three parts. Note the lesser wings spreading above the body to form a yoke (jugum).

fossa forms the roof of the nasal cavities, and it is perforated like a sieve by numerous olfactory nerves clothed in arachnoid sheaths that stream through it; hence, it is called the *cribriform plate* of the ethmoid (cribrum, L. = a sieve). The medial ends of two short canals, the *anterior* and *posterior ethmoidal foramina,* which lead from the orbital cavity, open at the side of the cribriform plate. They are not readily located unless traced from the orbital cavity. They transmit from the orbital cavity the anterior and posterior ethmoidal arteries and the anterior ethmoidal nerve. These arteries give off meningeal branches. The anterior ethmoidal a. and n. descend into

the nose through a slit, the *nasal slit*, at the side of the front of the crista galli. Laterally the fossa forms the roof of the orbital cavity; so, it is rounded and it rises high above the depressed roof of the nose. The *orbital plate of the frontal bone* forms the floor of the fossa lateral to the cribriform plate and it forms a roof for the frontal and ethmoidal air cells as well as for the orbit. Ridges corresponding to the cerebral sulci are conspicuous in the anterior and middle fossae.

The Middle Cranial Fossa has a small median part that lodges the hypophysis cerebri (pituitary gland) and two lateral expanded concave parts that lodge the temporal lobes of the brain. It is described in detail with the soft parts on page 626

The Posterior Cranial Fossa lodges the hind brain, which comprises the cerebellum, medulla, and pons. In life it is roofed in by the tentorium cerebelli; so, on each side it is limited above by (a) the posterior clinoid process; (b) the superior border of the petrous bone, and (c) the lips of the broad shallow groove for the transverse sinus, which continue horizontally backwards to the internal occipital protuberance. The *internal occipital protuberance* lies slightly above or below the level of the external occipital protuberance (or inion).

The *foramen magnum* is the largest bony foramen in the skull; so, it might be named the foramen maximum. It is unpaired and oval. It lies at the lowest part of the posterior fossa. It is narrower in its anterior half, where the condyles encroach on it, than behind. On the medial edge of each condyle there is a *tubercle* for the alar (check) ligament. *Stepping upwards and laterally from this tubercle, practically in a coronal plane, are the essential features of the fossa:* (1) the orifice of the *anterior condylar (hypoglossal) canal.* The canal passes laterally and forwards through the base of the condyle and transmits the hypoglossal (XII) nerve; (2) superolaterally is a *strengthening bar of bone* (tuberculum jugulare) which the accessory (XI), vagus (X), and glosso-pharyngeal (IX) nerves cross on their way to (3) the *jugular foramen*, and (4) half-an-inch above this is the orifice of the *internal auditory meatus.* Into it the auditory (VIII) and facial (VII) nerves disappear. So, the last six cranial nerves of both sides leave the skull practically in a coronal plane (*fig.* 640).

Surface Anatomy. A straight rod connecting both external *auditory meatuses* nearly passes through both internal auditory meatuses. This fact will assist you readily to relate the last six cranial nerves to the surface of the skull.

The *jugular foramen* is an interosseous foramen between the occipital and the petrous temporal bones. Descending to its most anterior part is a narrow groove which lies behind the *petro-occipital suture* and lodges the inferior petrosal sinus. Descending sinuously to its most posterior part is a wide groove for the *sigmoid sinus.* Nerves IX, X, and XI pass through its middle part. The sigmoid and transverse sinuses together constitute the lateral sinus.

The *groove for the lateral sinus* begins at the internal occipital protuberance and runs, 1st, horizontally laterally on the squama of the occipital bone and postero-inferior angle of the parietal bone to a point ¾" or less behind the external auditory meatus; 2nd, there it curves downwards and medially in the angle between the mastoid and petrous parts of the temporal bone and, leaving them, returns to the occipital bone—this time to the *jugular process;* 3rd, it then curves

forwards above the jugular process; and 4th, descends in front of it, grooving the medial side of the styloid process.

Two foramina for emissary veins commonly pass backwards from the groove: the *mastoid foramen* leaves the mastoid part of the course and runs through or near the occipito-mastoid suture; the posterior *condylar canal* leaves the jugular part and opens behind the condyle.

Between the foramen magnum and the dorsum sellae there is a broad thick plate of bone, the *basi-occipital,* which becomes thicker but narrower as it ascends. Between the apices of the petrous bones a synchondrosis joins it to the body of the sphenoid until the 22nd to 25th years when synostosis occurs—a useful index of age. Only a few millimeters of the body of the sphenoid are present between the synchondrosis (or synostosis) and the dorsum sellae, which is a free plate of bone. Between the foramen magnum and the internal occipital protuberance a thick bar, the *internal occipital crest*, gives attachment to the falx cerebelli. On each side of the crest the bone is concave for a cerebellar hemisphere, is translucent, and gives attachment on its external surface to nuchal muscles..

The Posterior Surface of the Petrous Bone tends to be flat and triangular. It is defined by grooves for *three sinuses*—the superior petrosal, inferior petrosal, and sigmoid. Its apex is joined to the sphenoid bone by a synchondrosis. Postero-superior to the internal auditory meatus is a small laterally directed pit, the remains of a large pit (*fig. 780 C, p. 794*) at birth over which the superior semicircular canal arched, hence called the *subarcuate fossa.* Postero-inferior to the auditory meatus is a medially directed *vertical slit*, the opening of the aqueduct of the vestibule, which lodges the ***saccus endolymphaticus*** (*fig. 757*). [The saccus endolymphaticus is a bag of fluid connected to the membranous inner ear by the ductus endolymphaticus. Lying extradurally, it can expand if the pressure in the ear increases. The apparatus may be compared with the yolk sac, vitelline duct, and intestine.] A *pyramidal notch* on the lower border of the petrous bone, just above the anterior end of the jugular foramen, lodges a ganglion of the IX nerve. The *aqueduct of the cochlea*, containing perilymph, opens at the deepest part of this notch and brings the inner ear into communication with the subarachnoid space (*fig. 757*).

THE MIDDLE CRANIAL FOSSA AND ITS CONTENTS

The middle cranial fossa (*fig. 647*). shaped like a butterfly, has a median part and two lateral parts

The Median Part admits the end of a finger. It has been likened to a bed with four clinoid processes or bed posts (Klyne, Gk. = a bed) each of which is pulled backwards by the tentorium. It lies above the body of the sphenoid, which is thin-walled because it is inflated by the right and left sphenoidal air sinuses. It is separated from the anterior cranial fossa by the curved line that unites the anterior clinoid processes and forms the anterior edge of the optic (chiasmatic) groove. It is bounded behind by the dorsum sellae whose superolateral angles are surmounted by the posterior clinoid processes.

Its features are: (a) the optic foramina and the optic groove connecting them. and (b) the sella turcica. The orifice of the *optic foramen* is somewhat compressed from above downwards. It lies between the inflated body of the sphenoid and the two roots of the lesser wing

of the sphenoid. The posterior root separates it from the groove or foramen for the carotid artery. The *optic (chiasmatic) groove* connecting the optic foramina behind the jugum—does not lodge the optic chiasma but part of the frontal lobe of the brain and related vessels. The *sella turcica* or Turkish saddle lies behind optic sulcus. It has 3 parts: (a) an olive-shaped swelling, the *tuberculum* diverticulum of the ectodermal stomatodaeum which became the anterior lobe of the hypophysis cerebri. The lower end of the canal is hidden by the vomer.

The anterior clinoid process is joined to the tuberculum sellae by a fibrous band that passes behind the internal carotid artery. It may be partly or completely ossified; the carotid artery then passes through a bony foramen.

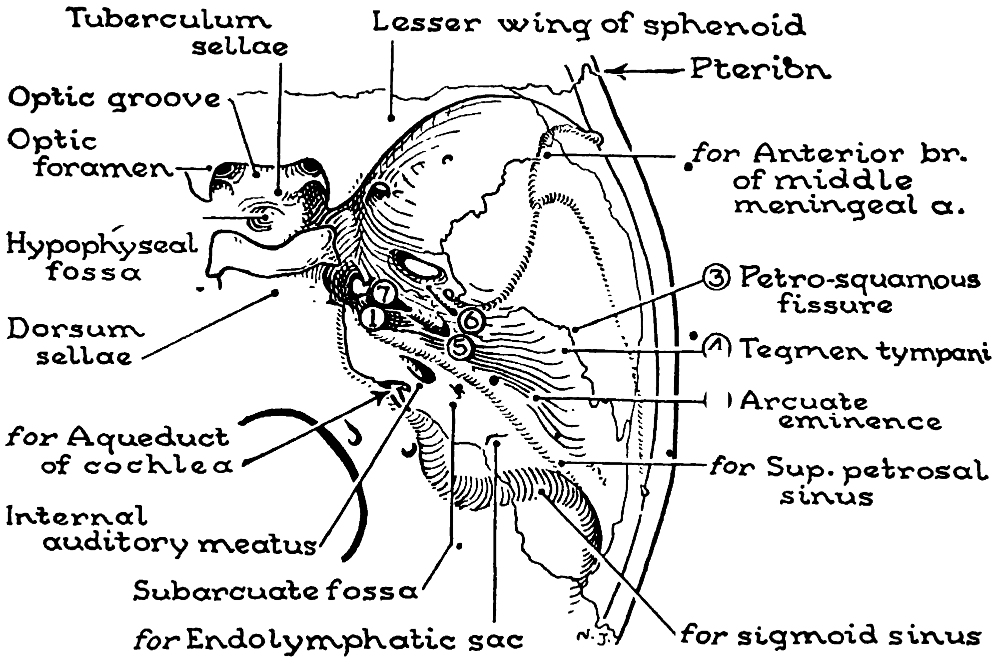


FIG. 647. The middle cranial fossa: Note the seven features on the cerebral surface of the petrous bone, (1) a depression for the trigeminal ganglion, (2) an elevation for the superior semicircular canal, (3) the remains of the petro-squamous fissure, (4) the tegmen tympani, (5) hiatus for the greater superficial petrosal nerve, (6) hiatus for the lesser superficial petrosal nerve, (7) the roof of the carotid canal which is commonly membranous.

sellae or pommel of the saddle; (b) behind this is the seat of the saddle, called the *hypophyseal fossa* because it lodges the hypophysis cerebri or pituitary gland; and (c) behind this rises the *dorsum sellae* or back of the saddle. Behind the tuberculum there is a pinpoint depression, the remains of the *cranio-pharyngeal canal*. It is of developmental interest because through it passed a

The Lateral Part. Each lateral part is limited in front by the lesser wing of the sphenoid, and behind by the superior border of the petrous bone. Laterally, it extends from the sharp inferior angle of the parietal almost to the blunt one. It is narrowest and lowest medially at the side of the body of the sphenoid. It comprises (a) the *greater wing* of the sphenoid, (b) the *pars petrosa*, and (c)

the *squama of the temporal bone*; each of these demands special attention.

THE GREATER WING OF THE SPHENOID. *The essential feature of the cerebral surface of the greater wing is a crescentic chain of foramina* (*fig. 648*): (1) The *superior orbital fissure* is comma-shaped and lies between the greater and lesser wings. It leads forwards into the orbital cavity. (2) Its detached lower end, called the *foramen rotundum*, is directed forwards towards the infra-orbital foramen but opens into the pterygo-palatine fossa. (3) The *foramen ovale* lies half-an-inch postero-laterally and opens downwards

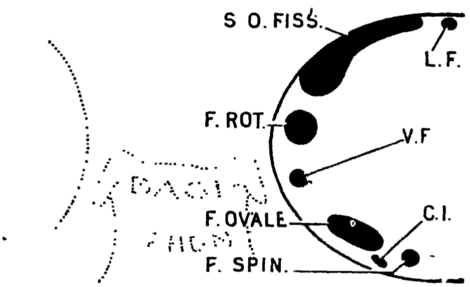


FIG. 648. Diagram showing the crescentic chain of foramina in the great wing of the sphenoid. The lacrimal f., Vesalian f., and c. innominatus, which transmit an artery, vein and nerve respectively, are not constantly present. This is a key diagram.

into the infra-temporal fossa. And (4) the *foramen spinosum* lies immediately postero-laterally, and also opens into the infra-temporal fossa. Each of the first three foramina transmits a division of the trigeminal nerve, V^1, V^2, and V^3. The fourth, i.e., the foramen spinosum, is situated at the postero-lateral angle of the greater wing. It takes its name from the spine that descends from the angle. It transmits the middle meningeal artery. The superior orbital fissure is separated from the optic foramen by one bar of bone and from the foramen rotundum by another bar; rarely one or other fails to develop. The foramina ovale et spinosum are parts of the petro-sphenoidal suture engulfed by the greater wing (*fig. 646*).

Three small and inconstant foramina may appear in this crescent: (5) A foramen situated lateral to the apex of the superior orbital fissure, allows the middle meningeal and lacrimal arteries to anastomose. (6) The foramen of Vesalius, situated between the foramen rotundum and foramen ovale, transmits an emissary vein. (7) The "canaliculus innominatus" transmits the lesser superficial petrosal nerve to the otic ganglion. Usually this nerve passes through either the petro-sphenoidal fissure or the foramen ovale. The postero-lateral angle of the greater wing is received between the squama and pars. petrosa of the temporal bone.

SQUAMA TEMPORALIS. The feature of the *cerebral surface of the squama* is the *groove for the middle meningeal artery*. This passes from the foramen spinosum on to the squama, curves forwards and laterally to a point corresponding to (i.e., opposite) the middle of the zygomatic arch, and divides into two terminal grooves for the anterior and posterior branches of the middle meningeal artery:

(a) The anterior groove regains the greater wing and proceeds to the sharp antero-inferior angle of the parietal bone (pterion) where it may remain an open groove, but more commonly it acquires overhanging edges or becomes a complete bony canal. Beyond the pterion it ascends to the vertex, again as an open groove that lies a finger's breadth (more or less) behind the anterior border of the parietal bone. Large grooves branch backwards from it, small ones forwards.

(b) The posterior groove curves backwards a finger's breadth (more or less) above and parallel to the zygomatic arch and supramastoid crest. To confirm this,

place your index finger above the arch and hold the squama to the light; its lower part is translucent.

Surface Anatomy (*fig. 649*). (1) The stem of the *middle meningeal artery*, passing through for the foramen spinosum, deep to the anterior border of the head of the mandible.

(2) The *anterior branch* of the middle meningeal artery crossing the pterion.

(3) *Macewan's Triangle* lies below the supramastoid crest and behind the suprameatal spine; a hole drilled here enters the tympanic antrum.

(4) A hole drilled above the supramastoid crest enters the middle cranial fossa.

(5) The *lateral sinus*, passing from inion to a point ¾″ or less behind the external auditory meatus to become the

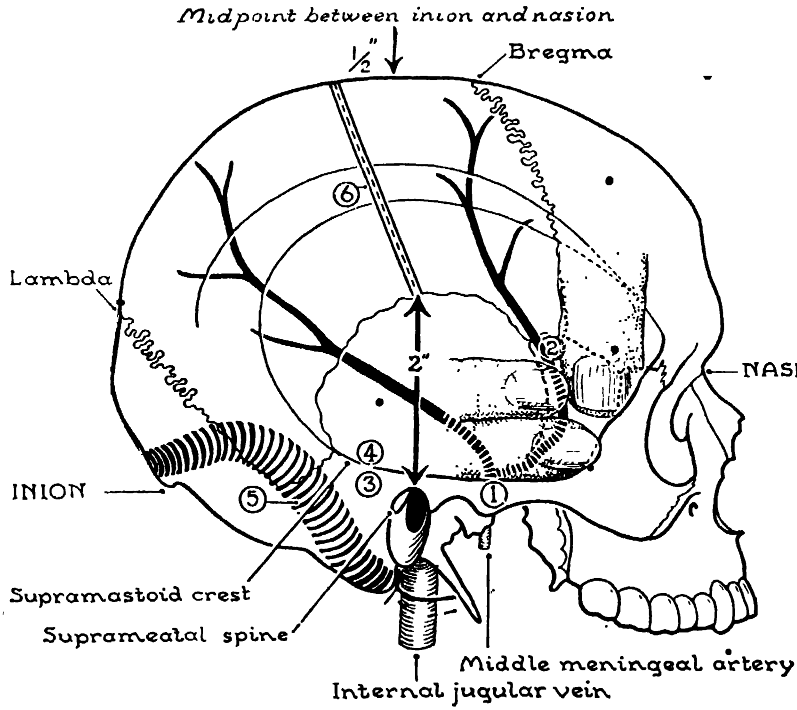


FIG. 649. Surface anatomy of the head.

internal jugular vein deep to the anterior border of the mastoid process.

(6) The *central fissure* of the cerebrum running from a point ½″ behind the mid inion-nasion point to a point 2″ above the external auditory meatus.

The *pterion* is the point where three bones meet (parietal, frontal, greater wing of sphenoid). To locate it, place the thumb behind the frontal process of the zygomatic bone and two fingers above the zygomatic arch, and mark the angle so-formed (Stiles). This great landmark overlies (a) the anterior branch of the middle meningeal artery, (b) the stem of the lateral cerebral fissure, and (c) a point a little above the level of the optic foramina.

Observe that lateral to the foramen spinosum the squama is strengthened by a *rounded bar of bone*, the articular eminence, seen on the under surface of the skull; and that behind the eminence the squama overlies the mandibular fossa

and is *thin and translucent*, explaining why a blow on the chin may fracture the middle cranial fossa. Hold the bone to the light.

THE PETROUS BONE. The features of the *cerebral surface of the petrous bone* are a medley: a depression and an elevation; a suture line, a thin (perhaps dehiscent) part; two minute foramina, and two grooves. (1) On the apex is a *shallow depression* for the trigeminal (semilunar) ganglion. It is continuous behind with the rounded part of the superior border of the petrous bone over which the root of the trigeminal nerve rolls. In front, the bone is often deficient, though bridged in life by fibrous tissue, and opens into the carotid canal. (2) An elevation, the *arcuate eminence*, rises like the tip of a finger above the superior border, a finger's breadth from the side of the skull. It overlies the superior semicircular canal. (3) The remains of the *petro-squamous fissure* run from behind the foramen spinosum first laterally, parallel to the superior border, and then backwards in a curve to the transverse sinus. It can be identified with the finger-nail. It is open until the second year and veins pass through it to the tympanum. (4) Medial to the fissure is the *tegmen tympani* or roof of the bony pharyngo-tympanic (auditory) tube, tympanum (middle ear), and tympanic (mastoid) antrum. It is thin and can be broken with the point of the forceps. (5) *Two foramina* open 4 and 8 mm. respectively behind the foramen spinosum, and from each a faint groove runs medially parallel to the superior border: (a) The lateral groove conducts the lesser superficial petrosal nerve to the canaliculus innominatus mentioned on page 628. (b) The medial groove conducts the greater superficial petrosal nerve across the depression for the trigeminal ganglion to the foramen lacerum.

The Foramen Lacerum. This large ragged foramen is placed between the apex of the pars petrosa and the attachment of the greater wing to the body of the sphenoid. The internal carotid artery emerges from it and is conducted sinuously in a groove on the side of the body of the sphenoid to the medial side of the anterior clinoid process.

Contents of the Middle Cranial Fossa:

(*1*) *Intradural* (*between two layers*):
Cavernous sinus.
Nerves III, IV, VI.
Nerve V.
I. carotid artery and sympathetic plexus.

(*2*) *Extradural:*
Middle meningeal vessels.
Superficial petrosal nerves—greater and lesser.

(*3*) *Median Compartment:*
Optic chiasma and nerve.
Hypophysis cerebri (pituitary gland).
Intercavernous sinus.

The oculomotor (N. III), trochlear (N. IV), abducent (N. VI), and the trigeminal (N. V) nerves run intradural courses in the middle cranial fossa and deserve the special consideration now given them. Nerves III and IV were seen to pierce the dura mater in the triangle between the free and attached borders of the tentorium cerebelli. Nerve V was seen ascending from the pons, curving over and therefore rounding off the medial part of the superior border of the petrous bone, and passing through the elliptica mouth of an evagination of dura mater, called the *trigeminal cave of Meckel.* The upper lip of the mouth contains the superior petrosal sinus, which therefore crosses nerve V like an aqueduct. Nerve VI was seen

piercing the dura in the posterior cranial fossa over the inferior petrosal sinus.

The Trigeminal Nerve (N. V). This nerve is described first because it can be dissected without disturbing the other nerves associated with the cavernous sinus.

On slitting up the mouth and roof of the trigeminal cave, the loose parallel fibers of nerve V are seen to become a plexiform swelling, called the *trigeminal* (semilunar or Gasserian) *ganglion.* The trigeminal ganglion is homologous with, and has the same structure as, the posterior root ganglion of a spinal nerve. It lies in a "finger tip" depression above the apex of the petrous bone. The depression extends forwards above the roof of the carotid canal, which here is usually fibrous; so, the ganglion is subjected to the pulsations of the underlying carotid artery.

From the anterior border of the ganglion 3 nerves proceed: the *mandibular nerve* (V^3) passes almost straight downwards through the foramen ovale, as though through a trap door, into the infratemporal fossa; the *maxillary nerve* (V^2) passes straight forwards through the foramen rotundum into the pterygopalatine fossa and ultimately appears on the face as the infra-orbital nerve; the *ophthalmic nerve* (V^1), which is the smallest of the three nerves, runs forwards and upwards and divides into 3 branches, the *naso-ciliary, frontal,* and *lacrimal,* which pass through the superior orbital fissure into the orbital cavity.

On inspecting a skull, you observe that the posterior lip of the f. ovale and the medial part of the f. rotundum are smooth and that the opposite parts are sharp. From this you conclude the directions taken by V^3 and V^2, and you are in a position just now to test these conclusions.

Nerves V^1, V^2, V^3 transmit sensory impulses from the three developmentally separate parts of the face (fronto-nasal, maxillary, and mandibular (*fig. 621*), and each sends a recurrent branch to the meninges; that from V^1 supplying the tentorium cerebelli. But, the trigeminal nerve also conveys motor fibers to the muscles of mastication; so, it is a mixed nerve. The motor root arises from the pons just medial (or supero-medial) to the sensory root, and joins the sensory part of the nerve beyond the ganglion, very much as in the case of a spinal nerve. The motor root is distributed solely with V^3, and essentially with the anterior part of V^3; so, it passes through the anterior part of the foramen ovale. This requires it to cross the ganglion from medial to lateral side; this it does inferiorly as a separate bundle of threads (*fig. 650*).

The Cavernous Sinus, described on page 618, extends from the side of the hypophysis cerebri and body of the sphenoid medially, to the maxillary nerve laterally; and from the superior orbital fissure anteriorly, to the inferior petrosal sinus posteriorly. Through it passes the internal carotid artery surrounded by sympathetic fibers; and applied to the lateral side of the carotid artery are the nerves of the ocular muscles—III, IV, and VI—in numerical sequence from above downwards (*fig. 651*). Nerve V^1 is a lateral relation of the anterior half of the sinus. Within the walls of the sinus, nerves IV and VI run horizontal courses; N. III inclines downwards, medial to them; N. V^1 inclines upwards lateral to them; and they all crowd through the medial end of the superior orbital fissure. The naso-ciliary nerve is the most important branch of V^1 for it is sensory to the eyeball, including the cornea. It arises from the medial side

of N. V^1 and accompanies N. VI. It cannot be seen until N. V^1 is everted.

How do the nerves traversing the cavernous sinus gain entrance to the orbit? All pass through the superior orbital fissure. In the ape this fissure is round—like the optic foramen—it has no lateral extension, as in man (*fig. 652*). In man it is the medial or primitive part of the fissure that the nerves utilize. They *crowd through* it, fairly tightly packed. The trochlear, frontal, and lacrimal nerves run side by side above the heads of the Lateral Rectus and are separated from the upper and lower divisions of the

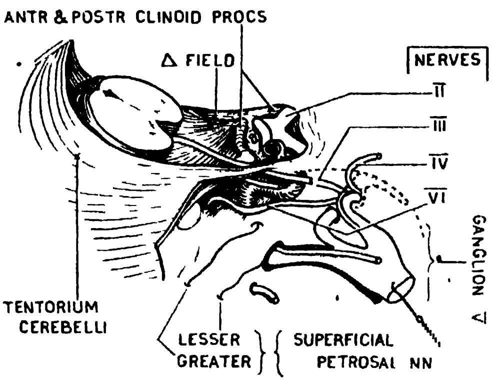


FIG. 650 Nerves IV and V have been divided and thrown forwards with ganglion V

oculo-motor, the abducent, and the naso-ciliary nerves, which pass between the two heads of the Lateral Rectus. But all are close together.

It should now be clear to you why nerves IV and VI run horizontal courses; why nerve III descends; and why the branches of V^1 ascend. Elaborating this you may say that the even nerves (IV, VI, V^2) run even or horizontal courses; and that the odd nerves (III, V^1, V^3) run oblique courses, either ascending or descending.

The Internal Carotid Artery lies in the carotid canal, separated from the trigeminal (semilunar) ganglion by a fibrous layer of dura. It emerges from the apex of the petrous bone into the foramen lacerum (it does not pass through the f. lacerum) and bending upwards enters the middle cranial fossa. There, embedded in the cavernous sinus, it ascends in a sulcus on the lateral wall of the body of the sphenoid (and therefore of the sphenoidal air sinus), makes a right-angled turn, and passes horizontally forwards to the anterior clinoid process. There it makes an acute-angled turn upwards, medially, and backwards below the anterior clinoid process and optic nerve to the angle between the optic nerve and tract where it divides into the *anterior* and the *middle cerebral artery*.

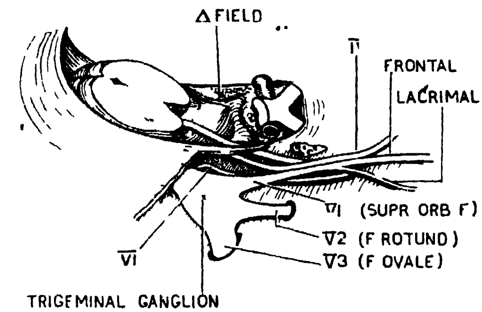


FIG. 651 The nerves related to the cavernous sinus.

It sends twigs to the trigeminal ganglion and hypophysis and gives off the ophthalmic and posterior communicating arteries.

Its intimate relations to the optic nerve and to the 3 nerves of the orbital muscles are indicated in figure 651. Of these, the abducent nerve clings most closely to it.

The Abducent Nerve (N. VI) supplies the chief abductor of the eyeball.

It arises at the lower border of the pons, the width of the olive medial to the facial nerve. It has an ascending and a horizontal course: thus, it ascends clamped

to the pons by the anterior inferior cerebellar artery, passes through the inferior petrosal sinus, bends sharply forwards over the petro-sphenoidal suture (or over the bone on one or other side of it), and enters on its horizontal course. In this it curves tightly round the lateral side of the internal carotid artery within the cavernous sinus, bears the relations to nerves III, IV, and V^1 mentioned above under cavernous sinus, crowds through the superior orbital fissure between the two heads of the Lateral Rectus, and enters this muscle on its ocular surface behind its middle.

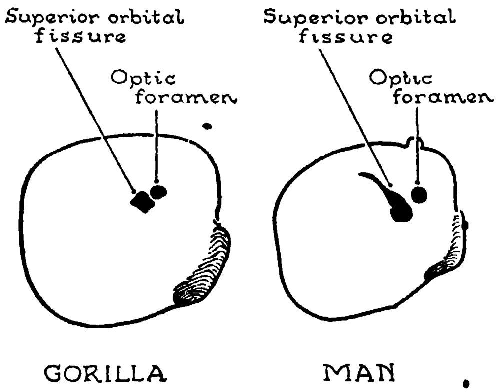


FIG. 652. The superior orbital fissure, in the ape and in man.

Sympathetic fibers and twigs from nerve V^1 join it in the sinus.

If nerve VI is paralyzed, the oblique muscles can abduct the eye to, but not beyond, the normal resting position.

The Trochlear Nerve (N. IV) supplies the ocular muscle that plays in a trochlea. It is the only nerve to rise from the back of the brain. On this account it has the longest intra-cranial course. Not only has it the longest course, it is also the most slender—the olfactory nerves excepted. It arises from the superior medullary velum, just below the inferior colliculus, winds round the midbrain under the free edge of the tentorium cerebelli, passes between the posterior cerebral and superior cerebellar arteries, pierces the apex of the triangle bounded by the free and attached margins of the tentorium, enters the cavernous sinus, runs horizontally along the horizontal part of the internal carotid artery between nerves III and VI.

Nerve III inclines downwards medial to N. IV, and the frontal nerve adheres to the lateral side of N. IV as it passes through the superior orbital fissure, above the origin of the muscles.

In the orbit N.IV lies below the periorbita of the bony roof, crosses the Levator Palpebrae and Superior Rectus and enters the upper border of the Obliquus Oculi Superior far back.

If paralyzed, double vision (diplopia) results on trying to look downwards and laterally.

The Oculo-motor Nerve (N. III) is motor to all the ocular muscles, except the two supplied by nerves IV and VI. It is also motor to the Levator Palpebrae, and to the ciliary muscle and sphincter of the pupil.

It arises from the oculomotor sulcus of the midbrain, passes between the same two arteries as the trochlear nerve, and enters the same triangular field of the dura mater. In its course it runs lateral to the posterior communicating artery, posterior clinoid process, internal carotid artery, and body of the sphenoid; and it enters the orbit between the two heads of the Lateral Rectus in two branches (*p. 641*).

Posteriorly, it is the highest structure in the cavernous sinus and it grooves the under aspect of the anterior clinoid process, but anteriorly it dips down, medial to the trochlear and frontal nerves, in order to enter the orbit with the abducent and naso-ciliary nerves.

The Anterior Clinoid Process is evi-

dently fashioned by its intimate relations: the free edge of the tentorium draws it backwards into a peak between the optic nerve medially, the oculo-motor nerve infero-laterally, and the internal carotid artery which is first inferior and then medial.

The Middle Meningeal Artery is a periosteal artery. It appears through the foramen spinosum, which is the hindmost foramen on the "crescent of foramina" (*fig. 648*). Adhering to the outer surface of the dura mater, it runs forwards and laterally for an inch or more and then divides into an anterior and a posterior branch, both of which are distributed above the level of the tentorium, as described on page 622.

Just before entering the skull, the middle meningeal artery sends the *accessory meningeal artery* through the foramen ovale to the trigeminal ganglion and the dura. Just after entering the skull, it sends two large twigs, which accompany the two superficial petrosal nerves, into the petrous bone: one to supply the facial nerve and anastomose with the stylo-mastoid branch of the posterior auricular artery; the other to the tympanum. The anterior branch of the artery anastomoses through the superior orbital fissure with the lacrimal artery; and, indeed, the lacrimal artery may spring from this branch.

The Middle Meningeal Vein passes through the foramen spinosum to the pterygoid plexus; it also joins the superior longitudinal sinus. And, since the groove it occupies on the parietal bone widens above, it is possible that the venous blood mostly flows upwards.

THE SUPERFICIAL PETROSAL NERVES, greater and lesser, are fine nerves that appear through foramina on the petrous bone. (a) Both nerves run medially, parallel to the superior border of the petrous bone, in faint furrows that conduct them to the f. lacerum and c. innominatus respectively; (b) both are embedded in the outer layer of dura mater; (c) both are secretory (parasympathetic) and perhaps contain taste fibers; and (d) both are relayed in peripheral ganglia.

The greater superficial petrosal nerve, a branch of the nervus intermedius (i.e., of the facial nerve), passes below the trigeminal ganglion, and descends into the foramen lacerum where it is joined by a sympathetic twig from the carotid plexus (called the deep petrosal nerve). Thereupon, it passes through the pterygoid canal (as the nerve of the pterygoid canal) to the spheno-palatine ganglion; whence it is relayed to the glands of the nose and palate and to the lacrimal gland.

The lesser superficial petrosal nerve is the continuation of the tympanic branch of the glossopharyngeal nerve. It is joined by sympathetic fibers when passing through the tympanum, and by a twig from the facial nerve when passing through the petrous bone. It appears in the middle cranial fossa lateral to the greater nerve, and leaves the skull through the canaliculus innominatus or foramen ovale to join the otic ganglion. Thence it is relayed to the auriculo-temporal nerve, which conducts it to the facial nerve, and so it reaches the parotid gland (*fig. 744*).

The Internal Carotid Nerve and Plexus, which is the upward continuation of the sympathetic trunk, accompanies the internal carotid artery through the carotid canal and cavernous sinus to be distributed with the branches of the artery. In the cavernous sinus it probably sends twigs to nerves, III, IV, V, and VI; other twigs pass through the superior orbital fissure to the ciliary ganglion. Stimulation of these fibers causes the pupil to dilate and the involuntary mus-

cles in the eyelids (sup. and inf. palpebral muscles, *fig. 657*) to contract, thereby widening the palpebral fissure.

THE ORBITAL CAVITY AND CONTENTS

The Bony Cavity. The orbital cavities are two pyramidal cavities each with four walls, an apex, and a base. Their medial walls are parallel, separated by the nasal cavities, and one inch (25 mm.) apart. Their lateral walls are at right angles to each other. The apex is the optic foramen (*fig. 653*). A probe passed along the lateral wall of the cavity traverses the optic foramen and meets a probe passed through the foramen of the other side at a right angle near the dorsum sellae. The base is outlined by the orbital margin and faces forwards and laterally. The lateral margin of the aperture is nearly an inch (20 mm.) behind the plane of the root of the nose. Primitively, the aperture is circular, as in lower animals, in the ape, and in the child at birth. In adult man it is no longer circular. The recession of his dental arcades below his orbits results in changes in the direction of the lines of masticatory force, and, no doubt as a sequel to this, the vertical diameter (35 mm.) of the orbital margin is less than the horizontal (40 mm.), which in turn is less than the antero-posterior (50 mm.). The aperture is more circular in females than in males; in yellow races than in white; and in white than in black. In the last it is oblong.

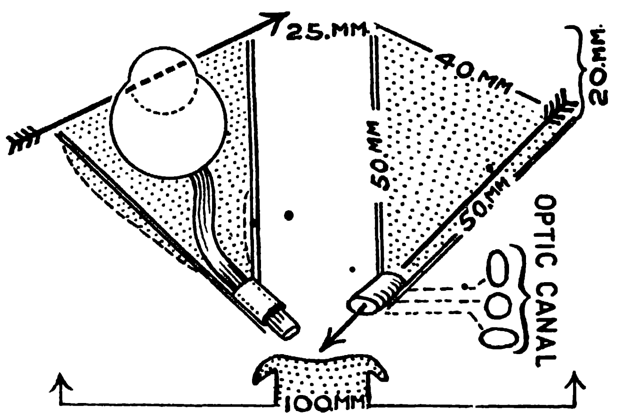


FIG. 653. The orbital cavities on horizontal section, and their dimensions.

THE ORBITAL MARGIN. Three bones—the *frontal, maxillary,* and *zygomatic*—contribute nearly equal thirds to the orbital margin: the frontal forming the upper margin and parts of both sides, the other two meeting at the middle of the lower margin where there is a tubercle, palpable through the skin. Each of these 3 bones transmits a cutaneous nerve—*supra-orbital, infra-orbital,* and *zygomatico-facial* (*fig. 621, p. 585*). The lower margin of the orbit, traced medially, becomes the (anterior) lacrimal crest of the frontal process of the maxilla (*fig. 654*). The upper margin, traced medially, becomes the (posterior) lacrimal crest of the lacrimal bone. Thus, the two crests bound the fossa for the lacrimal sac in front and behind. The margin therefore is spiral and may be likened to the margin of the obturator foramen. The palpebral fascia is attached to the (pos-

terior) lacrimal crest and is responsible for its razor-like sharpness. The margin is obviously much stronger laterally than medially.

The orbital margin is constricted, and is narrower than the part of the cavity that lies immediately behind it and that envelops the eyeball. The constricted aperture, the full anterior part of the cavity, the tapering hinder part, the elimination of angles, and the length of the optic foramen give a cast of the com-

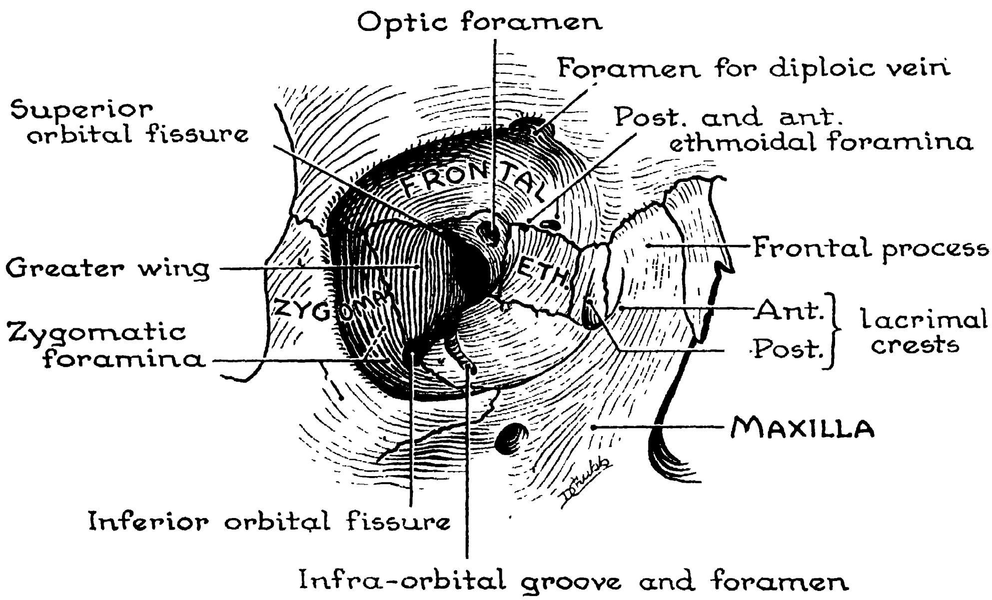


FIG. 654. The bony walls of the orbital cavity.

bined cavity and foramen a *pear-shaped appearance;* the stalk occupying the optic foramen.

THE OPTIC FORAMEN lies between the two roots of the lesser wing and the body of the sphenoid. It is 3—— 9 mm. long (about ¼ inch) and, having length, is in reality not a foramen but a canal. The distinction is significant. The result is that the optic nerve is in contact with the papery wall of the sphenoidal (or post. ethmoidal) air sinus for 3——9 mm. (*p. 757*); hence, a diseased sinus may involve the nerve of sight. The diameters of the canal, like those of the pelvic cavity, are greatest in the transverse diameter at the inlet; in the opposite diameter at the outlet; and in the middle it is circular.

FISSURES AND SUTURE LINES. A narrow bar of bone (the lower root of the lesser wing) separates the optic foramen from the upper limb of an extensive V-shaped fissure. The short upper limb of this V, the *superior orbital fissure*, separates the lesser and greater wings of the sphenoid, and continues laterally as a suture line to the junction between the zygomatic process of the frontal bone and the frontal process of the zygomatic bone. The long lower limb is the *inferior orbital fissure*. It completely separates the greater wing of the sphenoid from the maxilla, and extends to the zygomatic bone. A curved probe, passed backwards through the infra-orbital foramen,

traverses the infra-orbital canal and appears in the infra-orbital sulcus on the orbital plate of the maxilla. The sulcus ends at the middle of the inferior orbital fissure. A suture line runs from above the optic foramen to the nasion, and separates the frontal bone above from the ethmoid, lacrimal, frontal process of maxilla, and nasal bone below. Its hinder $\frac{3}{4}$ is horizontal and separates the roof of the cavity from the medial wall; its anterior $\frac{1}{4}$ is arched and on the face. The anterior and posterior ethmoidal foramina lie in the fronto-ethmoidal suture. A suture line runs backwards

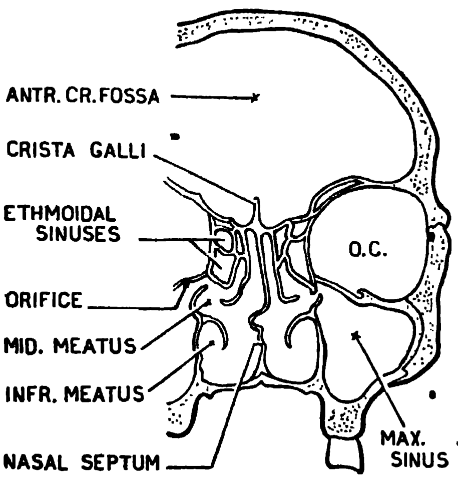


FIG. 655. Coronal section of skull.

from the naso-lacrimal canal to the inferior orbital fissure and separates the lacrimal and ethmoidal bones medially from the maxillary (and palatine) bones below.

THE WALLS AND BEYOND (*fig. 655*). The *lateral wall* is the strong wall; the other walls are thin and translucent. This is strange because in mammals lower than primates the orbital cavity and temporal fossa are continuous; there is no bony lateral wall. And, in many mammals (cat, pig) even the lateral part of the orbital margin is missing.

A perforation made (a) in the *roof* leads to the anterior cranial fossa, (if made anteriorly, it first traverses the frontal air sinus); (b) in the *floor*, to the maxillary air sinus; (c) in the *medial wall*, to the ethmoidal air cells; behind them, to the sphenoidal air sinus; and, *in front of them, to the atrium of the middle meatus of the nasal cavity;* and (d) in the *lateral wall*, to the temporal fossa or, behind it, to the middle cranial fossa.

The *periorbita* (periosteum) is easily detached, especially from the roof and medial wall. This is fortunate for the surgeon operating on diseased frontal and ethmoidal sinuses via the forehead and nasal cavity, because it greatly lessens the risk of breaking into the orbital cavity. It allows the surgeon to remove parts of the roof and medial wall without involvement of the orbital cavity.

ANGLES. Behind each of the four angles of the orbital margin there is a feature of note (*fig. 619*). Thus:

Supero-laterally—the fossa for the lacrimal gland.

Supero-medially—the fovea (or spine) for the trochlea of the Superior Oblique.

Infero-medially—the naso-lacrimal canal and origin of the Inferior Oblique.

Infero-laterally—the end of the inferior orbital fissure; which back.

FORAMINA. *The optic foramen* is the royal entrance to the orbital cavity; through it pass the optic nerve (N. II) within its 3 meningeal tubes (*fig. 657*), and the ophthalmic artery which supplies this region (*fig. 661*). *The superior orbital fissure* is the general entrance; through it pass motor nerves III, IV, and VI, sensory nerve V^1, sympathetic fibers, and the ophthalmic veins. *The inferior orbital fissure* is an accessory entrance; through it pass branches from V^2 (infra-orbital and zygomatic nerves), the infra-orbital artery, and a communicating

vein from the inferior ophthalmic vein to the pterygoid plexus. *Other openings* serve as exits—naso-lacrimal canal, infra-orbital groove, and supra-orbital, ant. ethmoidal, post. ethmoidal, and zygomatic foramina.

The Eyeball. The eyeball is an inch long (24.5 mm.) or half as long as the orbital cavity. It occupies the anterior half of the cavity; muscles and fat largely fill the posterior half. It projects beyond the orbital margin to the extent that a needle passed from the lateral margin to the bridge of the nose would pass behind the lens (*fig. 653*). On the other hand, the projecting supra-orbital margin and the bridge of the nose prevent a flat surface, such as a book, from striking the eye.

DEFINITIONS. The white posterior $\frac{5}{6}$ of the eyeball is the *sclera;* the transparent anterior $\frac{1}{6}$ is the *cornea.* These are structurally continuous at the *corneo-sclerotic junction.* The center of the corneal curvature is the *anterior pole;* the center of the sclerotic curvature behind is the *posterior pole.* A line joining the poles is the *antero-posterior, sagittal,* or *visual axis. The equator* encircles the globe midway between two poles in the coronal plane. *The horizontal axis* passes through the right and left points on the equator. *The vertical axis* passes through the upper and lower points on the equator. Vision is most acute where parallel rays of light strike the retina at the posterior pole. This part of the retina is the yellow spot or *macula lutea.* The optic nerve pierces the sclera three mm. to the medial or nasal side of the posterior pole at the *optic disc,* which is the blind spot. It is in line with the *orbital axis* (i.e., the long axis of the orbital cavity) which is quite different from the sagittal or visual axis of the eyeball.

THE OPTIC NERVE is developmentally different from other nerves; it is a part of the brain and like the brain it is surrounded by meninges and is bathed in cerebro-spinal fluid and its fibers are devoid of neurilemma. The optic nerve takes a sinuous course from optic foramen to optic disc and, so, does not restrain the movements of the eyeball. Its strong dural sheath begins at the optic foramen and extends to the sclera and blends with it. A probe passed through the optic foramen to the back of the globe lies within the sheath. Incise the sheath longitudinally, free the nerve, raise it, and cut it across immediately behind the

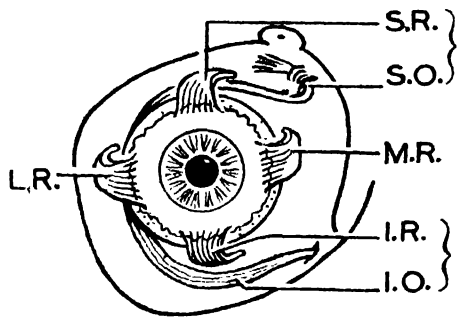


FIG. 656. The six muscles of the eyeball (from the front).

sclera and observe a central black spot—the *central artery and vein of the retina.*

The nerve cannot be withdrawn from its sheath because it adheres to it at the upper part of the optic foramen.

The Muscles of the Eyeball are: 4 Oculi Recti and 2 Oculi Obliqui.

The Recti (superior, inferior, medialis, lateralis) arise from the margin of a fibrous cuff, which is fixed behind to the optic foramen and to the dural sheath of the optic nerve, and which reaches laterally to embrace the medial end of the superior orbital fissure. They are inserted by bandlike aponeuroses into the sclera, 6–8 mm. behind the corneo-

sclerotic junction (*fig. 656*) and are there loosely covered with conjunctiva.

The Recti spread like the staves of a barrel: behind they are applied to the 4 walls of the orbital cavity; in front they grasp the globe. Each Rectus has an areolar sheath, and adjacent sheaths are united by areolar tissue--just as the sheaths of the Sterno-mastoid and Trapezius are united by the deep fascia of the posterior triangle—so, a cone is described, "*the muscle cone*" which encloses a space (*fig. 657*). A hammock of condensed areolar tissue, which is slung between the points of attachment of the palpebral ligaments to the orbital margin, supports the globe and extensions sent to the medial and lateral Recti act as check ligaments. Involuntary muscle fibers, the *Inferior Palpebral Muscle* (*fig. 657*), spread forwards from the Inferior Rectus into the lower lid. The origin of the Lateral Rectus is perforated in front of the superior orbital fissure by vessels and nerves that enter the cone of muscle; so, it has an upper and a lower tendon of origin.

The Levator Palpebrae Superioris is delaminated from the upper part of the Superior Rectus; so, they share the same nerve. When the Superior Rectus raises the eye, the Levator Palpebrae raises the lid. It arises above the Superior Rectus and is inserted in three layers. Of these: (1) The anterior layer passes through the Orbicularis and is attached to the skin of the lid. Its edges extend to the medial and lateral palpebral ligaments and are attached with them; so, they act as check ligaments preventing excessive retraction of the lid. (2) The intermediate layer is a sheet of involun-

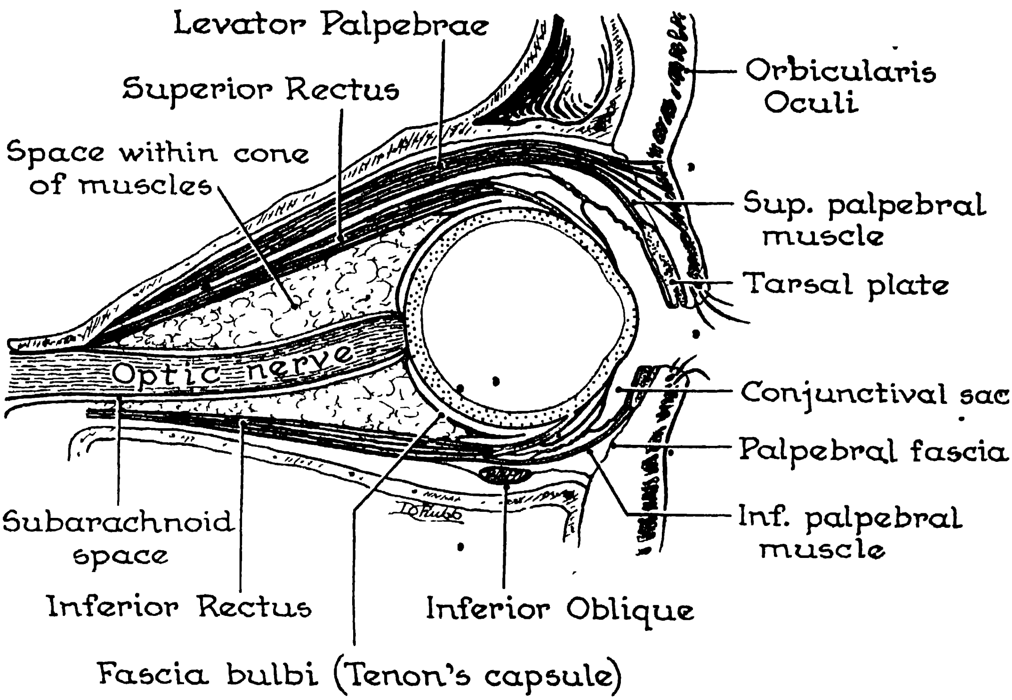


FIG. 657. Diagram of the orbital cavity, on sagittal section.

tary muscle, the *Superior Palpebral Muscle,* which is attached to the upper tarsal plate. (3) The posterior layer is fascial and passes to the superior fornix of the conjunctiva (*figs. 618, 619, 657*).

short distance (backwards) along each of them; in the case of the Superior Oblique—backwards beyond the trochlea.

The Obliqui (Superior et Inferior) are directed backwards and laterally from

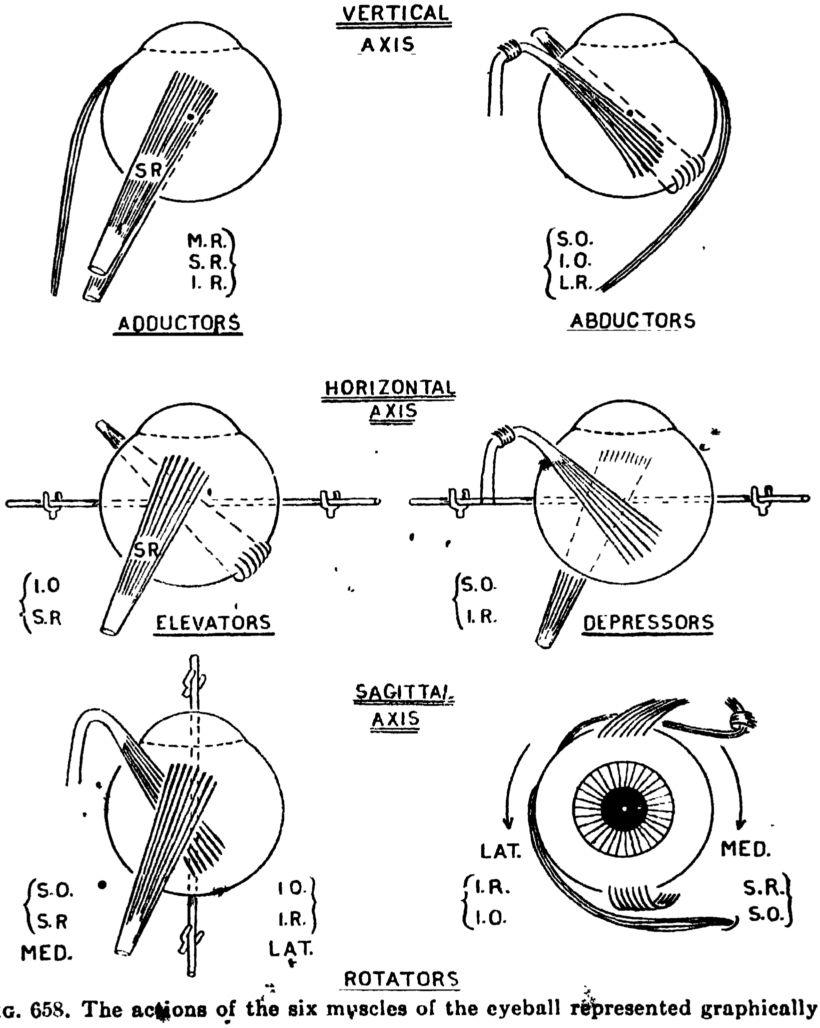


FIG. 658. The actions of the six muscles of the eyeball represented graphically.

The Fascial Sheath of the Eyeball. The sclera is invested in a bursal sheath, the *fascia bulbi* (capsule of Tenon), which extends from the optic nerve to the corneo-sclerotic junction. It is necessarily pierced by the six tendons acting on the globe, and it is prolonged for a just behind the supero-medial and infero-medial angles respectively of the orbital margin, to be inserted by fan-shaped tendons into the supero-lateral quadrant of the posterior half of the globe. The Obliquus Inferior arises lateral to the fossa for the lacrimal sac. The Obliquus

Superior arose primitively from a corresponding point on the roof, but it migrated backwards above the Medial Rectus to the fibrous cuff. It passes through a cartilaginous loop, the *trochlea*, at the supero-medial angle; so, the direction of its pull remains the same as that of the Obliquus Inferior. The Superior Oblique is necessarily tendinous at the trochlea and necessarily has a bursa there. It is not a digastric muscle, being tendinous from pulley to insertion. The two Obliques cross below the corresponding Recti—the S. Oblique below the S. Rectus; the I. Oblique below the I. Rectus.

The nerves enter the four Recti on their ocular surfaces behind their midpoints, and the two Obliqui on their borders——the upper border of the S. Oblique, the posterior border of the I. Oblique (*fig. 660*).

THE ACTIONS OF THE SIX MUSCLES (*fig. 658*) should not be memorized, because they can be worked out readily, provided it is appreciated: (1) that the muscles have three axes on which to act (sagittal, horizontal, vertical); (2) that the 4 Recti are arranged around the axis of the orbital cavity which is different from the sagittal axis of the globe (*p. 638*); hence, the M. S. and I. Recti act as adductors; and (3) that the two Oblique muscles pass behind the vertical axis and are inserted behind the equator; hence, they act as abductors. Further, (4) the Recti acting as retractors of the eyeball and the Obliqui as protractors keep it in balance.

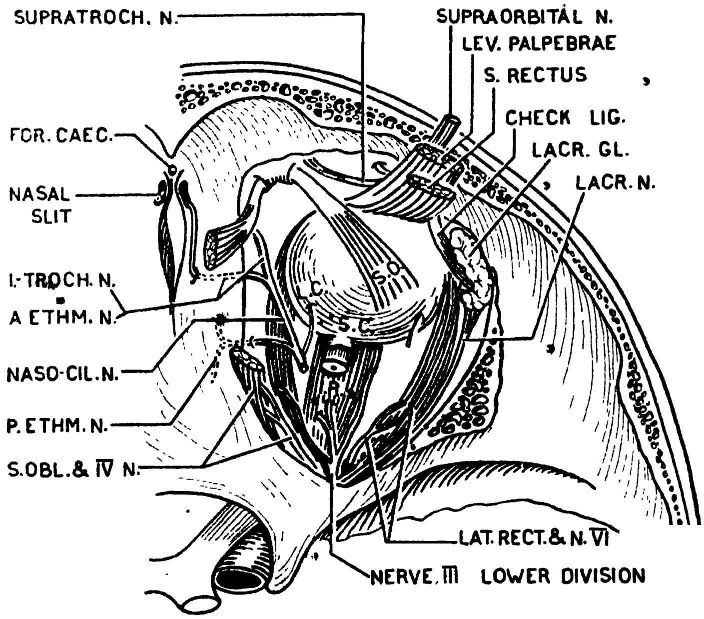


FIG. 659. Dissection of the orbital cavity, from above.

Nerves of the Orbit:

(a) Special Sense—II.
(b) Motor—III, IV, and VI.
(c) Sensory—V^1 (frontal, lacrimal, and nasociliary branches).
(d) Autonomic —— (a) sympathetic fibers from the carotid plexus, and (b) parasympathetic fibers travelling with N. III.

SPECIAL SENSE. *The Optic Nerve* (II)

reaches the orbit through the optic foramen and comes to lie within the cone of muscles (*fig. 657*).

All the other nerves crowd through the superior orbital fissure: three of these, the *trochlear*, *frontal*, and *lacrimal*, pass above the origin of the Lateral Rectus and lie between the roof of the orbit and the cone of muscles; the others pass in a bundle through the Lateral Rectus, dividing it into an upper and a lower head of origin, and lie within the cone of muscles. The three branches of the ophthalmic nerve (V^1) ultimately become cutaneous; the other nerves do not extend beyond the orbit.

MOTOR (*fig. 660*). *The Abducent Nerve* (VI) clings to the ocular surface of the Lateral Rectus and enters its middle.

The Trochlear Nerve (IV) enters the upper border of the Superior Oblique far back.

The Oculomotor Nerve (III) supplies the remaining 3 Recti, the Inferior Oblique, and the Levator Palpebrae; and it conveys parasympathetic fibers to the ciliary ganglion, thence they are relayed to the ciliary muscle and iris. The oculomotor nerve is the nerve employed when examining an object close at hand, as in reading, because it causes convergence of the eyes (adductor muscles), accommodation of the lens or focusing (ciliary muscle), and contraction of the pupil (circular fibers of the iris) thereby shutting out peripheral light. The 3rd nerve passes between the two heads of the Lateral Rectus as an upper and a lower division: of these the upper supplies the Superior Rectus and Levator Palpebrae; the lower sends a branch below the optic nerve to the Medial Rectus, a branch to the Inferior Rectus, and a branch that runs along the lateral border of the Inferior Rectus to the Inferior Oblique. The nerve to the Inferior Oblique delivers the parasympathetic branch to the ciliary ganglion.

SENSORY. *The Ophthalmic Nerve* (V^1) passes through the superior orbital fissure as 3 branches: frontal, lacrimal, and naso-ciliary. The *frontal nerve* passes above the Lateral Rectus, runs between the orbital plate of the frontal bone and the Levator Palpebrae, and divides into supra-orbital and supratrochlear branches. These pass through the supra-orbital notch and above the trochlea respectively and are distributed to the scalp and eyelid. The *lacrimal nerve* follows the upper border of the Lateral Rectus, pierces the lacrimal gland, and ends in the upper lid. It gives sensory fibers to the lacrimal gland and delivers to it secretory fibers received from the zygomatic nerve. The **naso-ciliary nerve** is of supreme importance on account, not of the nasal distribution, but of the ciliary. The naso-ciliary nerve passes between the two heads of the Lateral Rectus, crosses above the optic nerve, runs on the medial wall of the orbit between the Superior Oblique and Medial Rectus, sends (a) a twig through the posterior ethmoidal foramen to the sphenoidal and ethmoidal cells, sends (b) the *infratrochlear nerve* below the trochlea to the tear sac and region all around it, and continues as the *anterior ethmoidal nerve*. The *anterior ethmoidal nerve* passes through the anterior ethmoidal foramen, appears in the anterior cranial fossa extradurally, passes through the nasal slit at the side of the crista galli, supplies ethmoidal cells and the front of the nasal cavity, occupies the groove on the back of the nasal bone, appears on the dorsum of the nose between the nasal bone and cartilage, and extends to the tip of the nose. Its ciliary branches are described in the next paragraph.

THE AUTONOMIC NERVES OF THE EYE-

BALL. Far back between the optic nerve and the Lateral Rectus there is a small brown ganglion, the **ciliary ganglion.** It is the relay station for the parasympathetic fibers of nerve III. These fibers pass to the ganglion via the nerve to the Inferior Oblique and leave it via 12 or more *short ciliary nerves.* The short ciliary nerves pierce the scleral coat around the optic nerve, and run forwards between the scleral and choroidal coats. They are motor to the ciliary muscle and to the Sphincter Pupillae (circular fibers of the iris).

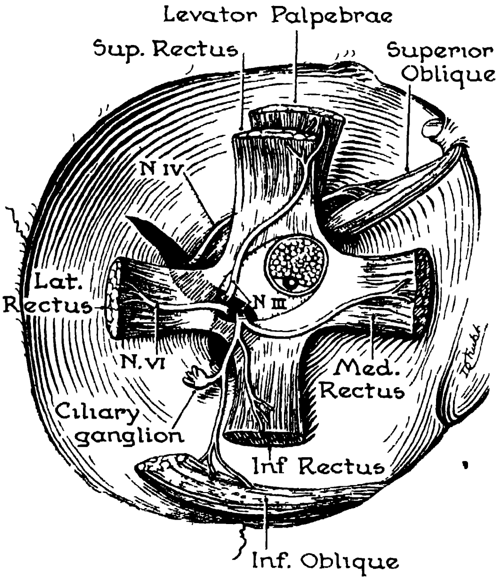


FIG. 660. Sketch of the distribution of cranial nerves III, IV, and VI.

All *short ciliary nerves,* however, are not parasympathetic. Thus, a branch from the sympathetic and another from the naso-ciliary nerve enter the ciliary ganglion and, without synapsing, pass out with the short ciliary nerves: the sympathetic fibers are vaso-constrictor; the naso-ciliary fibers are sensory.

Two *long ciliary nerves* arise from the naso-ciliary nerve, as it crosses the optic nerve; they accompany the short ciliary nerves. They are mixed—sensory and sympathetic: the sympathetic fibers joined the naso-ciliary nerve in the cavernous sinus; they are motor to the Dilator Pupillae (radial fibers of the iris).

Sensation from the tip of the nose and from the cornea is subserved by the respective divisions of the naso-ciliary nerve. A rough foreign body, such as a cinder, in the eye—if there were no ciliary nerves to detect it—would cause inflammation and ulceration of the cornea (*figs. 718, 764 and p 648*).

Arteries (*fig. 661*). *The Ophthalmic Artery* supplies the contents of the orbit and sends branches beyond the orbit. It arises from the internal carotid artery, passes through the optic foramen below the optic nerve, pierces the dural sheath of the nerve laterally, and finds itself free within the cone of muscles. It then crosses above the optic nerve between the ophthalmic vein in front and the naso-ciliary nerve behind.

Branches must be accounted for to the various structures within the orbit—three coats of the eyeball, optic nerve, muscles, fat, and lacrimal gland.

The central artery of the retina, with its companion vein, pierces the sheath of the optic nerve inferiorly half-an-inch or so behind the eyeball, runs in the center of the optic nerve through the sclera to the retina, and supplies its inner layers. It is an end artery. Obstruction leads to instant and total blindness.

Posterior ciliary arteries (6 or more) divide into several branches which pierce the sclera around the optic nerve to end in the choroid. Two of these arteries, called *long posterior ciliary aa.,* run forwards, one on each side, between sclera and choroid to anastomose with the anterior ciliary arteries. The choroid nourishes the outer layers of the retina which themselves are non-vascular.

Anterior ciliary arteries, derived from the muscular branches to the Recti, pierce the sclera behind the corneo-scleral junction, anastomose with a long posterior ciliary artery on each side, and supply the ciliary body and iris. But before piercing the sclera, they supply twigs to the deep conjunctival plexus (episcleral) around the corneal margin. This plexus is clinically important because it shares in the congestion of the

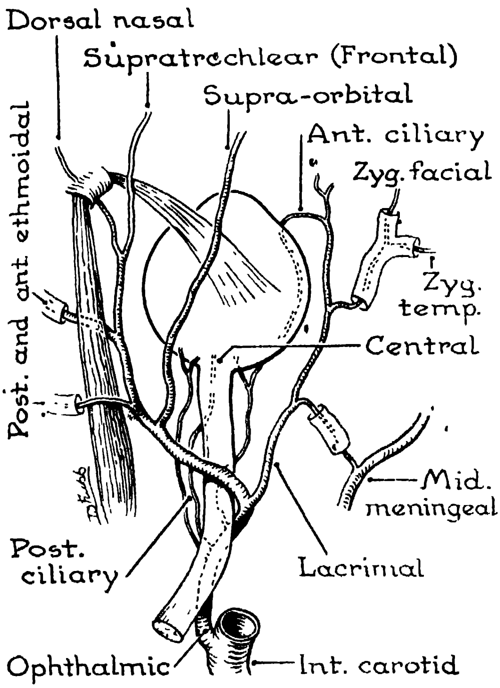


FIG. 661. Diagram of the ophthalmic artery and its branches.

deep vessels when the iris or ciliary body is inflamed. The cornea has no blood supply; the sclera has but little. Various twigs pass to the muscles and the fat.

The lacrimal artery joins its nerve, supplies the gland, and extends to the upper lid. It gives off a meningeal branch (*p. 634*). Being the lateral artery of the orbit, it has to supply twigs to the *muscles*, *conjunctiva*, and *lids*.

Six branches, including the lacrimal a., pierce the cone of muscles, stream out of the orbit in company of correspondingly named nerves, and anastomose freely with branches of the external carotid artery. They are: the *supra-orbital*, *supratrochlear*, *dorsal nasal* (with the infratrochlear nerve), *lacrimal*, and the *anterior* and *posterior ethmoidal arteries.* The first five end on the forehead or face; the last named ends in the nasal mucosa.

Veins. *The superior ophthalmic vein* begins as the union of the supra-orbital and supratrochlear veins, and it anastomoses with the anterior facial vein. It crosses above the optic nerve, passes through the superior orbital fissure and ends in the cavernous sinus.

The inferior ophthalmic vein begins on the floor of the orbit, communicates through the inferior orbital fissure with the pterygoid plexus, crosses below the optic nerve and ends either in the superior vein or in the cavernous sinus. Tributaries correspond to branches of the artery.

LYMPH VESSELS have not been described within the orbit.

The Lacrimal Gland (*fig. 619 C*) is a serous gland placed behind the *supero-lateral* angle of the orbital margin, between the orbital plate of the frontal bone and the conjunctiva. It is indented by the lateral border of the Levator Palpebrae and thereby made J-shape, just as is the submandibular gland by the lateral border of the Mylo-hyoid. So, it has a larger deep (or orbital) lobe and a smaller superficial (or palpebral) lobe. Less than a dozen ducts open near the fornix of the conjunctiva; those of the orbital lobe cross the palpebral lobe.

Exposure. To expose the *orbital lobe* of the gland, cut through skin, Orbicularis Palpebrae, and palpebral fascia along the supero-lateral quadrant of the orbital margin. To expose the *palpebral lobe,*

evert the upper lid and incise the fornix of the conjunctiva.

Vessels and Nerves. Lacrimal artery and nerve. The lacrimal nerve contains sensory fibers and conveys secretory and sympathetic fibers received from the zygomatic nerve. The secretory fibers travel via the nervus intermedius, greater s. petrosal n., nerve of the pterygoid canal, spheno-palatine ganglion, and zygomatic nerve, thence by a communicating branch to the lacrimal nerve (*fig. 744*).

Other Contents. Three branches of the maxillary nerve (V^2) pass through the inferior orbital fissure and, though not concerned with the orbital contents, technically they enter the orbital cavity: (a) the infra-orbital nerve clings to and perforates the floor; (b) the zygomatic nerve clings to and perforates the lateral wall and sends secretory and sympathetic fibers to the lacrimal gland, (c) the orbital branch of the spheno-palatine ganglion supplies the sphenoidal and ethmoidal cells, periosteum, and the Muscle of Muller that bridges the inferior orbital fissure.

Twigs of the infra-orbital artery supply the floor of the orbit and the lacrimal sac.

The Eyeball (The Dissection of the Eyeball). A good way to acquire a general knowledge of the anatomy of the human eyeball is through the dissection of the eyeball of the ox, because it is large and obtainable without difficulty. It is necessary to remove the adnexa preparatory to hardening the ball in formalin or alcohol overnight. The conjunctiva is only loosely attached to the sclera and is easily separated from it up to the corneal margin. The epithelium of the cornea is firmly adherent and cannot wrinkle. In man it consists of five or six layers of cells. The four Recti, two Obliqui, and the Retractor Bulbi (a muscle not present in man), are to be cleaned and removed with the fat around the ball. The thick tube of dura mater surrounding the optic nerve is to be cleaned and its attachment to the globe defined.

The ball or globe of the eye has *three concentric coats* (*figs. 662, 663*) whose parts from behind forwards are:

1. Outer or fibrous coat:
   Sclera and cornea.
2. Middle or vascular coat:
   Choroid, ciliary body, and iris.
3. Inner or retinal coat:
   Outer pigmented.
   Inner nervous.

These enclose three refractive media —aqueous humour, lens, and vitreous body.

Dissection. Holding the globe firmly in the left hand, shave off from the neighborhood of the equator thin slices of the sclera, which is grayish in color, until the choroid, which is told by its jet blackness, is exposed. Then holding the globe loosely so as to relieve tension carefully insert the point of a probe through the hole just made and detach the choroid all round it. With scissors snip away the part of the sclera so freed. And so, with the alternate aid of probe and scissors, and working meridionally between anterior and posterior poles, remove a third or more of the outer coat. This will expose an underlying elliptical area of the choroid. The point of the probe must be directed continuously against the sclera in order that the delicate middle and inner coats shall not be punctured. With a sweeping movement detach the middle coat from the corneo-scleral junction where it is firmly attached.

Observation. The space behind the cornea is the *anterior chamber*. It is continuous through the *pupil*, which is oval in the ox and circular in man, with the *posterior chamber*. Both chambers contained *aqueous humor* in life. The lens touches the back of the *iris* at the pu-

pillary margin. The probe should be passed through the pupil and behind the iris into the posterior chamber.

In man the *cornea* forms one-sixth of the outer coat of the globe; the *sclera* five-sixths. The cornea is more convex than the sclera, i.e., it is a segment of a smaller sphere. The cornea is about 1 mm. thick; the sclera is thinner, especially at the equator. The two, however, are structurally continuous at the *corneo-sclerotic junction*, where there are several features of note: (a) The edge of the cornea is overlapped by the sclera like a watch glass in its case. (b) Running circularly around the sclera there is a minute cleft, the *scleral sinus*, visible with a lens. (c) The middle coat has a white zone, 6 mm. broad, the *ciliary muscle*, which is continuous in front with the iris and behind with the choroid. The ciliary muscle arises from the sclera at the corneo-sclerotic junction and is there firmly attached. (4) The acute angle between the cornea and the iris (actually between sclera and iris) is the *irido-corneal angle*. It is crossed by interlacing strands, the *pectinate ligament*, that pass backwards from the edge of the posterior elastic membrane of the cornea to the region of the iris and sclera, and the spaces enclosed are lined with the mesothelium of the anterior chamber. The anterior chamber communicates through the spaces with the scleral sinus which in turn communicates with the scleral veins.

DISSECTION. Cut away the remaining part of the cornea and, after freeing structures with the probe, carefully enter the blade of the scissors through the pupil and cut a large square flap in the iris. Raise the flap and enlarge it backwards through the ciliary muscle into the choroid, thereby exposing the jelly-like vitreous body.

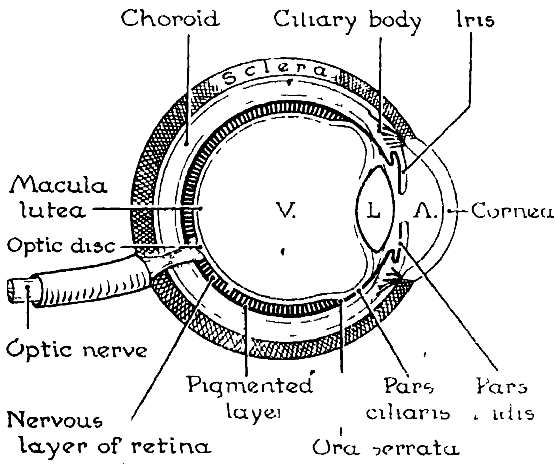


FIG. 662

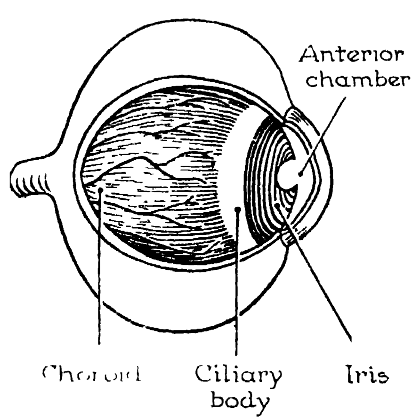


FIG. 663

FIG. 662. Scheme of the eyeball, anteroposterior section.
FIG. 663. Dissection of the eyeball of an ox, the sclera is in part removed.

OBSERVATION. On the surface of the raised flap (in front of the ciliary muscle) a number of short black fingerlike processes, the *ciliary processes*, resembling the fascia dentata of the brain, are apparent. When in position, they occupy the peripheral part of the posterior chamber. They may reach to the periphery of the lens. Handle them with the probe.

They are about seventy in number. They are black because the pigmented retina is adherent to them (see below). The peripheral margin of the lens also is exposed, so is the transparent capsule of the vitreous body, called the *hyaloid membrane.* The hyaloid membrane passes forwards in folds, which the ciliary processes occupy, to near the margin of the lens where it divides into an anterior and a posterior layer. The posterior layer continues to encapsule the vitreous. The anterior and stronger layer, the *suspensory ligament of the lens,* blends

DISSECTION. Using probe and scissors, cut circularly through each of the three coats at the equator: first through the remaining part of the sclera, next through the choroid, and then through the retina. The globe can now be separated into anterior and posterior halves; the vitreous body remains with the anterior half.

OBSERVATION. In man the fibers of the optic nerve pierce the sclera in bundles, 3 mm. to the nasal side of the posterior pole of the globe, and at this point the sclera is cribriform and weak. Next they pierce the choroid and the outer layer of the retina, which adheres

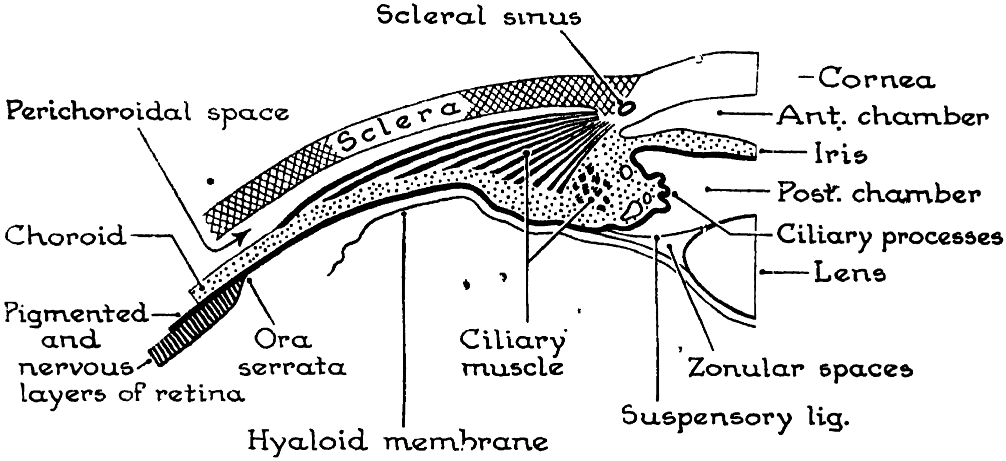


FIG. 664. The ciliary region, enlarged. (After Cunningham's Anatomy.)

with the front of the lens capsule. A triangular canal, the *zonular spaces* (canal of Petit) encircles the margin of the lens between the two layers, and it is possible with a hypodermic syringe to cause a colored fluid to flow round it.

The *ciliary muscle* (*fig. 664*) is triangular on cross section. Its fibers radiate backwards from the corneo-sclerotic junction to the choroid which they pull forwards when they contract, thereby causing relaxation of the suspensory ligament and allowing the lens to become more convex. The muscle possesses an inner bundle of circular fibers.

to the choroid, and then, after forming a circle, the *optic disc,* which is a blind spot, 1.5 mm. in diameter, they spread out as the inner layer of the retina. After death the retina is gray and lusterless like an exposed photographic film. No longer supported by the vitreous it detaches itself from the choroid everywhere except at the disc, and it becomes wrinkled and perhaps broken. The *central artery* and *vein* each pass through the disc as two vessels, which bifurcate and pass to the four quarters of the inner layer of the retina.

The *choroid* adheres to the inner surface

of the sclera, but it is easily detached and the *perichoroidal space* opened up. The inner surface of the sclera is stained with pigment (lamina fusca) except along a number of meridional lines where the ciliary nerves adhere. If the choroid is sponged under water, the pigment is washed away and a network of vessels is seen.

Turn to the anterior half of the globe. The *retina* becomes thin along a wavy line, the *ora serrata*, a short distance behind the ciliary muscle. Behind this the retina is true optic retina, but in front (where rays of light cannot reach) the retina is represented by two layers of cubical cells, the outer of which is pigmented. These two layers are carried forwards over the ciliary body and iris to the margin of the pupil.

The Refractive Media. The *cornea* does the chief focussing; the lens is for fine adjustment. The *lens*, derived from the same layer as skin, hardens or cornifies with advancing age. The hardening begins at the center, and accommodation becomes increasingly difficult. The ox being young, the lens is soft throughout. When hardened, a lens may be split into layers somewhat like an onion. The *vitreous body* is embryonic tissue comparable to that in the umbilical cord.

VESSELS. *Arteries.* About a dozen *posterior ciliary aa.* pierce the sclera around the optic nerve and enter the choroid far back. Two of these, *long ciliary aa.*, one on each side, run forward between sclera and choroid and enter the ciliary body where they form a circle which is joined by the *anterior ciliary aa.* The ciliary body and iris are supplied by these.

The *anterior ciliary aa.* are branches of muscular vessels. Before piercing the sclera, they anastomose with the conjunctival arteries and give off episcleral twigs.

The *central a.* supplies the inner layers of the retina; it is an end artery.

The function of the vascular choroid is to nourish the outer layers of the retina; hence, where the retina is thin (i.e., in front of the ora serrata) the choroid is much less vascular.

The cornea is bloodless.

Veins. Four choroidal veins pierce the sclera behind the equator.

NERVES. *Fibers of N. III*, relayed in the ciliary ganglion as short ciliary nerves, pierce around the optic nerve, pass to the ciliary muscle and iris, causing accommodation (of the lens) and contraction of the pupil. The *sympathetic fibers* act on the radial fibers of the iris causing dilatation of the pupil. They are also vaso-motor. Branches of the *naso-ciliary nerve* (V^1) accompany the short ciliary nerves and are sensory to the cornea.

DEVELOPMENT. The retina developed as an outgrowth from the brain and, so. is of ectodermal origin. In its early stage it resembled an inflated rubber balloon with a hollow stalk which was continuous with the cavity of the 3rd ventricle. On the appearance of the lens, which developed from the overlying skin surface and likewise is of ectodermal origin, the balloon was deflated and invaginated and made cup-shaped, hence the two layers of the retina.

The central artery originally passed through the hyaloid canal in the vitreous body and anastomosed in the capsule of the lens, which early was vascular. Before birth, this capsule atrophies and the artery, ceasing to supply it, confines itself to the retina and so becomes an end artery.

CHAPTER 22

THE ANTERIOR TRIANGLE OF THE NECK

Subdivisions (*fig. 665*). The anterior triangle of the neck is bounded by the the median line from chin to manubrium, by the anterior border of the Sterno-mastoid, and by the lower border of the jaw together with the hinder part of the posterior belly of the Digastric It is subdivided into three subsidiary

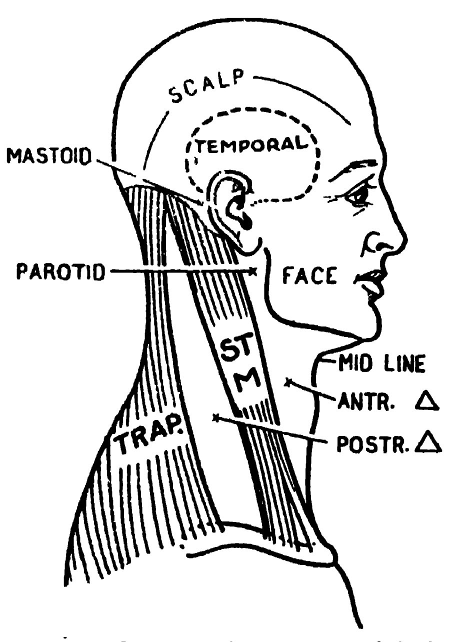


FIG. 665. The superficial regions of the head and neck.

triangles, named, *digastric, carotid,* and *muscular*, by the anterior and posterior bellies of the Digastric and the superior belly of the Omohyoid. The region of the neck bounded below by the body of the hyoid bone and on each side by the anterior belly of the Digastric is the *submental triangle.* It is unpaired and will be considered as part of the median line of the neck. The region above the posterior belly of the Digastric and behind the ramus of the jaw is the *parotid region* Though the parotid region is in the neck, it is beyond the confines of the anterior triangle.

Landmarks and Vertebral Levels (*fig. 666*). The only vertebra that can be identified from the front is the *atlas* (*fig. 701*). The tip of its transverse process, much more prominent than all other cervical transverse processes except the seventh, lies between the angle of the jaw and the tip of the mastoid process. It is best felt by pressing upwards behind the angle of the jaw. The other transverse processes can be felt on deep pressure but not identified individually.

If you drop the chin slightly, in order to render the cervical fascia lax, and run your fingers downwards in the median line of the neck from chin to suprasternal (jugular) notch, you will palpate in succession the *body of the hyoid bone*, the *laryngeal prominence* of the thyroid cartilage (Adam's apple), the *arch of the cricoid cartilage*, and two inches of trachea. The lower rings of the *trachea* are more easily distinguishable than the upper 3 or 4 which are covered by the *isthmus of the thyroid gland.*

The hyoid bone is joined to the thyroid cartilage by the *thyro-hyoid membrane*; the thyroid cartilage to the cricoid cartilage by the *median crico-thyroid lig.*; and the cricoid cartilage to the trachea by the *crico-tracheal membrane.*

With the head in the anatomical position (eyes looking forward) the hyoid bone lies above the level of the chin, at the angle between what are really the floor of the mouth and the top of the neck.

While palpating the hyoid bone (the chin must be dropped) perform the act of swallowing and note that it is pulled upwards and forwards. The thyroid and cricoid cartilages also are felt to rise. Run the index fingers along the hyoid bone to the tips of its greater cornua, which lie near the anterior borders of the Sterno-mastoids, and note the bone can be moved from side to side like a shuttle; so, to palpate one cornu it is necessary to steady the other. The right and left laminae of the thyroid cartilage and its superior cornua are also readily felt provided the opposite side is steadied.

The hyoid bone lies at the level of the body of the 3rd cervical vertebra, the thyroid cartilage at the level of the 4th and 5th, the cricoid cartilage at the very important level of the 6th.

The Platysma Myoides (= muscle-like plate) is a rhomboidal, subcutaneous muscle sheet. It extends from the face above to the level of the 2nd rib below It is superficial to the first two bones in the body to ossify (i.e., clavicle and mandible) and it crosses the entire length of both. It is continuous above with the facial muscles, but the most anterior fibers are attached to the lower border of the mandible and others decussate with the opposite Platysma for an inch behind the chin. Its anterior border slopes from this point to the sterno-clavicular joint. Thus, the Platysma leaves the median line of the neck and the lowest part of the anterior triangle uncovered; whereas it covers the lowest part of the posterior triangle. It is as though the sheet had been pulled off the anterior triangle in an attempt to cover the posterior one.

It lines the side of the neck, which is concave, and when it contracts its fibers by straightening ease a tight collar and take pressure off the underlying veins of the neck.

Its action, therefore, is "anti-sphincteric". The facial nerve supplies it on its deep surface. Branches of the anterior cutaneous nerve of the neck pierce it.

Other *subcutaneous muscles*, apart from those about the head, are the occasional axillary arches (*p 93*, the representatives in man of the muscles with which horses flick off flies), the Palmaris Brevis, and the Dartos. Of these, the Dartos is an involuntary muscle supplied by sympathetic fibers.

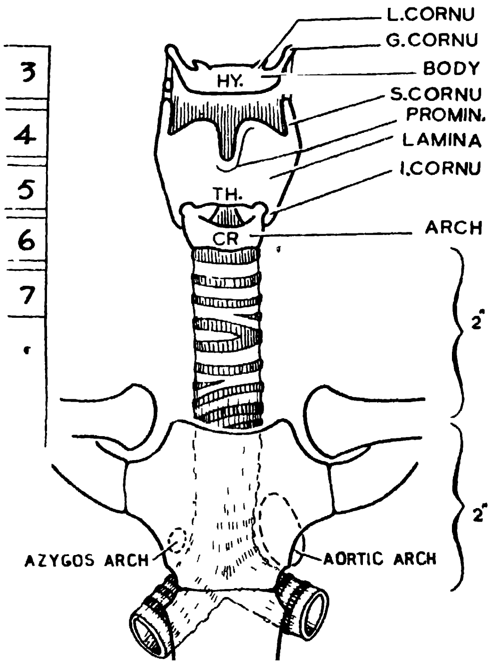


FIG. 666. Landmarks and vertebral levels.

Deep Fascia. The neck is invested in a sleeve of deep fascia similar in texture to that investing the limbs but differing from that covering the thorax and abdomen. This sleeve splits behind to enclose the Trapezius, covers the posterior triangle, splits in front to enclose Sterno-mastoid, and covers the anterior triangle. According to rule, it is attached

to all the exposed bony parts and ligaments it encounters. These are: *behind*, the ligamentum nuchae; in *front*, the whole length of the body and great cornua of the hyoid bone; *above*, the lower border of the jaw, the zygomatic arch (to reach which it crosses the parotid gland), the cartilage of the ear, the mastoid bone, and the superior nuchal line; *below*, it splits an inch or so above the manubrium into two layers, which are attached to the front and back of the suprasternal (jugular) notch, thereby enclosing a space, the *suprasternal space* of Burns. Lateral to this it blends with the subcutaneous parts of the clavicle, acromion, and posterior border of the spine of the scapula between the attachments of the Sterno-mastoid and Trapezius above, and the Pectoralis Major and Deltoid below. It encloses the submandibular (*fig. 692*) (submaxillary) and parotid salivary glands, and forms slings which bind down the intermediate tendons of the Digastric and Omohyoid.

The carotid sheath, prevertebral fascia, and sheath of the thyroid gland are described on pages 656, 698, 672, and fig. 629.

The Superficial Veins (*fig. 628*). The *superficial temporal vein* and the *internal maxillary vein* unite in the parotid gland to form the *posterior facial vein*. This divides into two branches: the posterior branch joins the *posterior auricular vein* to form the *external jugular vein*; while the anterior branch joins the *anterior facial vein* at the angle of the jaw to form the *common facial vein*. The common facial vein pierces the deep fascia to join the *internal jugular vein* at the level of the hyoid bone. The external jugular vein descends vertically, crosses the Sterno-mastoid, pierces the deep fascia at the posterior border of the Sterno-mastoid an inch above the clavicle, then receives the *transverse cervical, suprascapular, anterior jugular* and other veins, and finally pierces a second layer of fascia to end in the *subclavian vein*.

The right and left *anterior jugular veins*, unequal in size and asymmetrically placed, begin in the submental region, run near the median line, pierce the deep fascia an inch or so above the manubrium to enter the suprasternal space. Here a cross-channel unites them. Each then turns laterally and runs along the upper border of the clavicle between Sterno-mastoid and "the strap muscles" to end in the external jugular vein.

Note. Not infrequently an *unnamed vein*, lying long the anterior border of the Sterno-mastoid, connects the common facial and anterior jugular veins. This *connecting vein* is important, because it may become a main channel, equal in size even to the internal jugular itself and mistakable for it.

Three Superficial Nerves appear in the anterior triangle (*fig. 627*). They are (1) the *great auricular nerve* which passes to the parotid gland where it divides, (2) the *anterior cutaneous nerve* of the neck which supplies the entire front of the neck, and (3) the *cervical branch of the facial nerve*. The last last named, though subcutaneous (actually subplatysmal) is a motor nerve. It passes within a finger's breadth of the angle of the jaw and sends one branch downwards to supply the Platysma and anastomose with the anterior cutaneous nerve, and another forwards along the lower border of the jaw. This latter branch enters the face by crossing the lower border of the jaw with the facial artery and the anterior facial vein. On the face it anastomoses with the mandibular branch of the facial nerve and helps it to supply the inferior labial muscles.

The Median Line of the Neck

BOUNDARIES AND SUBDIVISIONS (*fig. 667*). The median line is bounded above by the slightly diverging *anterior bellies of the Digastrics*, below by the converging *Sterno-thyroids*, and between these by the nearly parallel *Sterno-hyoids* It is divided into *suprahyoid* and *infrahyoid parts* The suprahyoid part is limited

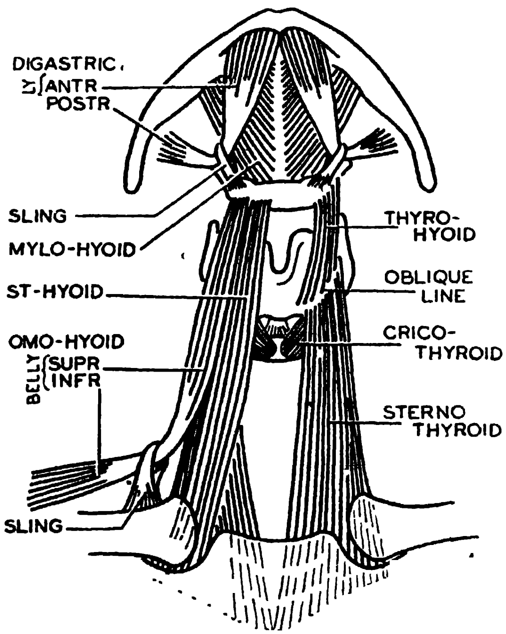


FIG. 667. The muscles bounding the median line of the neck.

below by the body of the hyoid and on the sides by the anterior bellies of the Digastrics, which converge to be attached to the digastric impressions at the sides of the symphysis menti. The triangle formed thereby is the *submental triangle.* The Mylo-hyoids form its floor. Here the anterior jugular veins begin; here lie the submental lymph glands, which drain the median parts of the lower lip and floor of the mouth and the tip of the tongue.

If you examine the cadavera in the dissecting rooms, you will find the anterior bellies of the *Digastrics* and the *Mylohyoids* in process of change. Once they formed a single muscle sheet: in a percentage of subjects separation is complete; in others various types and degrees of incomplete separation are encountered. Later the two muscles will be found to have a common nerve supply (*fig. 677*).

MEDIAN STRUCTURES AND VESSELS CROSSING THE LINE. The *hyoid bone* resembles the iliac crest in that no muscle crosses it from one end to the other. It is, therefore, subcutaneous; and therefore the deep fascia is attached to it. The suprahyoid twig of the lingual artery and the infrahyoid twig of the superior thyroid artery follow its upper and lower borders and anastomose with their fellows across the median plane. The *thyro-hyoid membrane* passes from the upper border of the thyroid cartilage to the upper border of the body and greater cornua of the hyoid, and a *retro-hyoid bursa* is present between the membrane and the body of the hyoid. The median *crico-thyroid ligament* unites the adjacent borders of the cricoid and thyroid cartilages. It is very strong and is partly visible between the upwardly diverging borders of the Crico-thyroid muscles. The *crico-thyroid branch* of the superior thyroid artery anastomoses with its fellow in front of the ligament and sends a (median) twig through the ligament into the larynx. The Crico-thyroids are the tensors of the vocal cords. The *isthmus of the thyroid gland* generally covers the 2nd, 3rd (and 4th) tracheal rings, and branches of the opposite superior thyroid arteries anastomose along its upper border. A long process of the thyroid gland, called the *pyramidal lobe*, present in less than 50% of subjects,

extends from the isthmus towards, or to, the hyoid bone.

In front of the lower cervical rings of the trachea are: (1) One or more cross communications between the anterior jugular veins within the suprasternal space of Burns. (2) The (right) innominate artery and (3) the left innominate vein may peep above the suprasternal (jugular) notch. (4) The inferior thyroid veins descend to the left innominate vein, and (5) an occasional thyroidea ima artery ascends from the (right) innominate artery to the thyroid gland.

The Infrahyoid Muscles, four in all, are the depressors of the larynx. Owing to their shape they are sometimes referred to as the "strap muscles". They belong to the same superficial ventral sheet of muscles as the *Rectus Abdominis.*

The primitive infrahyoid muscle mass splits into a superficial and a deep layer; each of which splits again into two. The superficial layer splits longitudinally into medial and lateral parts, the *Sterno-hyoid* and *Omo-hyoid*; the deep layer becomes attached to the oblique line of the thyroid cartilage and is thus divided into upper and lower parts, the *Thyro-hyoid* and *Sterno-thyroid.* The four infrahyoid muscles will later be seen to be supplied by branches of the anterior rami of cervical nerves. 1, 2, and 3 via the hypoglossal nerve and the ansa hypoglossi. These branches approach the muscles from the lateral side, pass between their superficial and deep layers, and enter them on their opposed surfaces or lateral borders (*fig. 668*).

The Sterno-hyoid and Omo-hyoid arise side by side from the front of the body of the hyoid, and diverge very slightly from the median plane as they descend. The Sterno-hyoid is attached to the posterior aspect of the capsule of the sterno-clavicular joint and to the bone on each side of the joint. The Omo-hyoid leaves the Sterno-hyoid abruptly below the level of the cricoid cartilage, passes deep to the Sternomastoid, crosses the posterior triangle, and reaches the upper border of the scapula beside the notch. Later, these two muscles and their fellows of the opposite side will be seen to lie within a common sheet of fascia which passes in front of the larynx and trachea, and which is attached

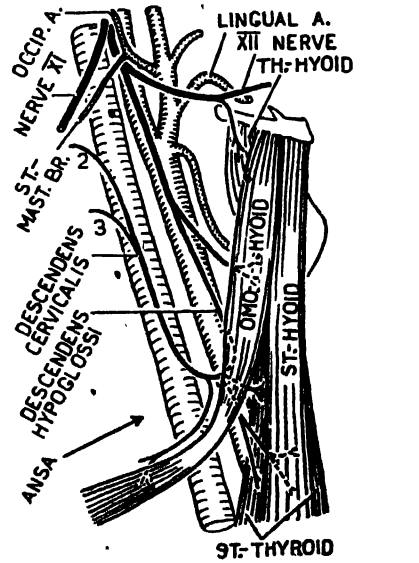


Fig. 668. The infrahyoid muscles and their nerves.

to the carotid sheath laterally, and to the back of the manubrium, and clavicle, inferiorly. The Omo-hyoid, like the Digastric, has two bellies. They are united below the level of the cricoid cartilage by an intermediate tendon and are held down by a sling derived from the fascia just mentioned. Unlike the Digastric, the two bellies of the Omo-hyoid are supplied by the same nerve, for the inferior belly is but an extension backwards of the superior belly. Now and then it fails to extend farther back than the clavicle.

The deep layer of muscles is divided into a part above and a part below the oblique line of the thyroid cartilage, where both are attached. The upper part, the THYRO-HYOID, is superficial to the thyro-hyoid membrane. It extends upwards and laterally to the adjacent parts of the body and greater cornu of the hyoid. It, therefore, projects lateral to the Omo-hyoid and appears in the carotid triangle. The lower part, the STERNO-THYROID, converges on its fellow as it descends until their medial borders meet at the center of the manubrium. The lower attachment extends from the center of the manubrium to the first costal cartilage.

The Cervical Viscera. GENERAL REMARKS. There are certain important similarities between the abdomen and the front of the neck which it is helpful to bear in mind. Thus, posteriorly both regions are bounded by secondary flexures of the vertebral column, called the lumbar and cervical flexures respectively. To the sides of the vertebral bodies at these flexures, muscles (Psoas and Longus Cervicis respectively) are attached. Anteriorly, the one region extends from the lower end of the sternum to the symphysis pubis; the other, from the upper end of the sternum to the symphysis menti. In the anterior wall of the abdomen the Rectus Abdominis extends from pubis to chest wall. It is a segmental muscle, supplied by somatic segmental (intercostal) nerves and partly subdivided by tendinous intersections. Similarly, in what may be called the anterior wall of the neck, a muscle, which temporarily we shall call the "*Rectus Cervicis*", because it is the upward continuation of the Rectus Abdominis, extends from chest wall to mandible. It likewise is a segmental muscle, supplied by somatic segmental (C. 1, 2, and 3) nerves, and subdivided by tendinous intersections. The "Rectus Cervicis" has acquired attachments to the thyroid cartilage and to the hyoid bone. Its infra-hyoid parts are the Sterno-hyoid and Omo-hyoid, the Sterno-thyroid and Thyro-hyoid, described above; its supra-hyoid part is the *Genio-hyoid.* The Genio-hyoid extends from the genial tubercle of the mandible (*fig. 690*) to the body of the hyoid bone (*fig. 795*).

Through the abdomen run the stomach and the intestines; through the neck run the pharynx and oesophagus (with their off-shoot the larynx and trachea). These are but different levels of the digestive tube; and, in the vagus and sympathetic they have a common nerve supply. True, there is no peritoneal cavity in the neck. To liken the thyroid gland to the pancreas does not strain the comparison, for both glands arise as hollow outgrowths from the wall of the digestive tract It is to these *four visceral tubes*—pharynx and oesophagus, larynx and trachea - and the *thyroid gland*, that we are applying the collective term, "*cervical viscera*".

It is highly desirable at this stage to master the following facts about "the cervical viscera" and to observe the attachments of the *constrictors of the pharynx.* If possible they should be studied both in a prepared dissection and in a cross-section of the neck.

The Pharynx, which is the upper end of the digestive and respiratory tubes, extends from the base of the skull to the level of the 6th cervical vertebra where, at the lower border of the cricoid cartilage, it is continuous with the oesophagus. At this same level the larynx is continuous with the trachea (*fig. 6C9*). The posterior wall of the trachea is applied throughout its entire length to the anterior wall of the oesophagus.

A constrictor is to the pharynx what circular muscle is to the intestine. On contracting it reduces the caliber. The nasal, oral, and laryngeal cavities open into the anterior wall of the pharynx; so, the constrictors are present only in the posterior and side walls. There are three constrictors, *Superior*, *Middle*, and *Inferior*. Each is fan-shaped, and each is

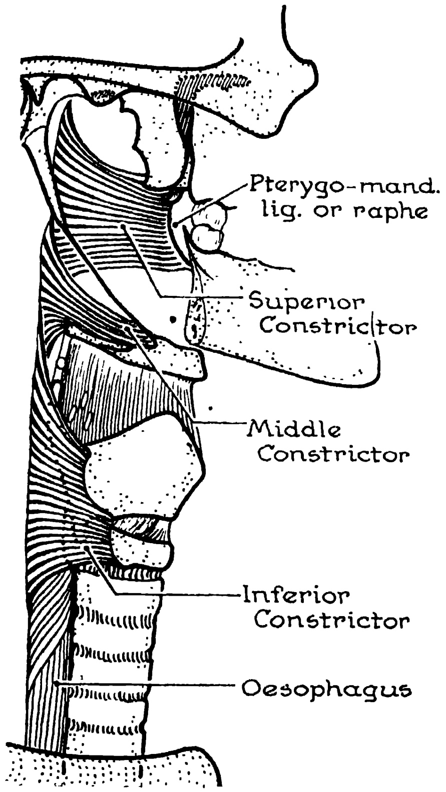


FIG. 669. The three Constrictors of the pharynx.

attached by its narrower end or handle to the framework of the side wall of the nasal, oral, and laryngeal cavities. The bases of the fans of opposite sides meet in the median plane behind. The Inferior Constrictor overlaps the Middle, and the Middle overlaps the Superior in telescope fashion; and on the side walls of the pharynx there are spaces above and below their narrow handles of origin. Through these spaces pass vessels, nerves, muscles, and the pharyngo-tympanic (auditory) tube.

It is simplest to begin by placing the Middle Constrictor (*fig. 669*). *The Middle Constrictor* arises in the angle formed by the greater and lesser horns of the hyoid bone and the lowest part of the stylo-hyoid ligament. From this its

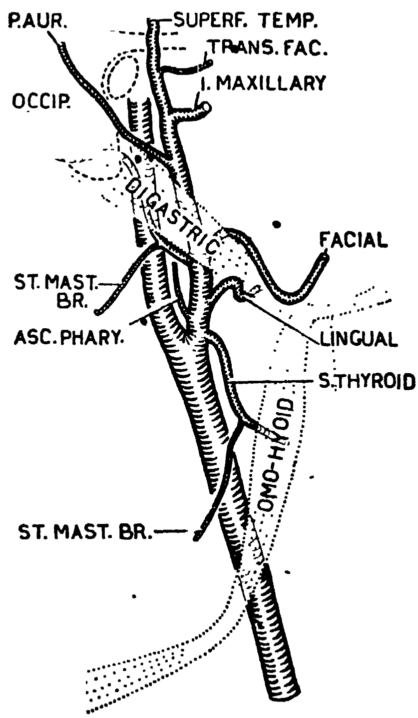


FIG. 670. The three carotid arteries and the branches of the external carotid.

fibers fan out and meet those of the opposite side in the median plane.. The origin of the *Inferior Constrictor* extends from the upper border of the thyroid cartilage to the lower border of the cricoid cartilage. Between these two points it gains attachment to the outer surface of the lamina of the thyroid cartilage and there assists the Sterno-thyroid and Thyro-hyoid to create an

oblique line. The presence of the Crico-thyroid prevents the Inferior Constrictor from gaining direct attachment to the outer surface of the cricoid cartilage; so, it becomes attached to the areolar covering of the Crico-thyroid and converts it into a tendinous arch of origin; just as the Diaphragm does to the fascia covering the Psoas and Quadratus Lumborum, and the Levator Ani to the fascia covering the Obturator Internus. The upper fibers of the Inferior Constrictor fan out and meet those of the opposite side outside those of the Middle Constrictor. Its lowest fibers are horizontal and blend with those of the esophagus. The *Superior Constrictor* is continuous, for practical purposes, with the Buccinator. It arises from the pterygo-mandibular raphe and from the bone at each end of the raphe, namely, the lowest part of the posterior border of the medial pterygoid lamina, and the mandible behind the last molar tooth. Its diverging upper and lower borders are curved. The upper one reaches the pharyngeal tubercle at the center of the under surface of the basi-occiput; the lower one is overlapped by the Middle Constrictor.

The Thyroid Gland (fig. 671) is wrapped around the front and sides of the four cervical "visceral tubes". It consists of a right and a left lobe connected near their lower poles by an isthmus, which crosses the (1st), 2nd, 3rd, and (4th) rings of the trachea. Each lobe lies on the side of the trachea and oesophagus, and extends upwards on the side of the pharynx and larynx, till arrested by the attachment of the Sterno-thyroid to the oblique line on the lamina of the thyroid cartilage. It intervenes between the "four visceral tubes" and the carotid sheath, and when enlarged it either overlaps the sheath or displaces it laterally (*fig. 672*).

The Carotid Sheath. The common and internal carotid arteries, the internal jugular vein, and the vagus nerve extend from the cranial cavity to the thorax and in so-doing traverse the neck in some

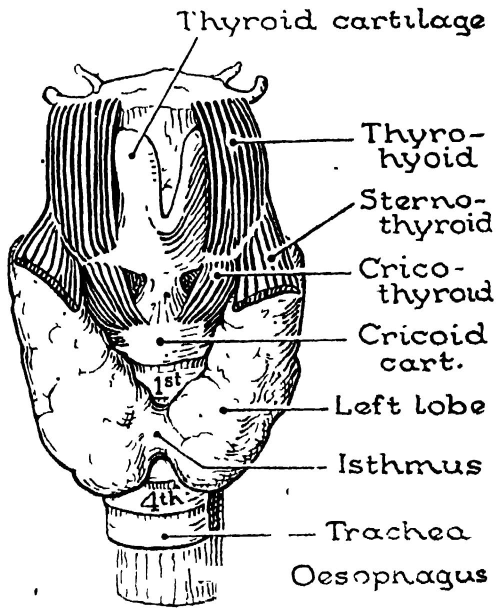


FIG. 671 The thyroid gland, front view

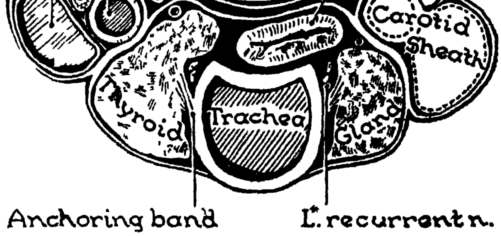


FIG. 672 The thyroid gland and the carotid sheath, on cross section

condensed areolar tissue called the carotid sheath (*fig. 629*). The arterial stem is medial, the vein lateral, and the vagus nerve posterior in the angle between

them. Behind the arterial stem, but outside the sheath, is a smaller nerve, the *sympathetic trunk:* it likewise traverses the neck. In front of the arterial stem, but outside the sheath, is the descendens hypoglossi nerve (*fig. 668*): it is confined to the carotid triangle. The sheath is applied to the side of the cervical viscera—oesophagus, pharynx, and, thyroid gland. These relationships are best appreciated in a cross-section.

The Carotid Triangle

The carotid triangle is bounded by the anterior border of the Sterno-mastoid, the superior belly of the Omo-hyoid, and the posterior belly of the Digastric; it has its apex at the body of the hyoid bone. The posterior belly of the Digastric occupies **a key position** in the neck and on that account it will be described now at some length.

The Posterior Belly of the Digastric (*fig. 674*) arises from the lateral of the two grooves on the under aspect of the mastoid bone. It is united to the anterior belly by an intermediate tendon which is held down to the junction of the body and cornu of the hyoid by an inverted sling of fascia.

Be sure to locate on yourself its two bony points of attachment, and to note that a straight line joining them crosses the tip of the transverse process of the atlas and passes deep to the angle of the jaw. This is the course taken by the posterior belly of the Digastric. It separates the carotid triangle below from the digastric triangle and the parotid region above.

The Stylo-hyoid is a portion of the posterior belly of the Digastric that has moved forwards on to the root of the styloid process. It lies along the upper border of the posterior belly, splits to let the intermediate tendon pass through it, and it is inserted into the body of the hyoid bone.

The posterior belly of the Digastric and the Stylo-hyoid, like the Platysma and the muscles of the face and scalp, are supplied by the facial nerve, and like them are quite superficial. The mastoid process and the muscles inserted into it conceal the origin of the posterior belly, and the parotid and submandibular glands

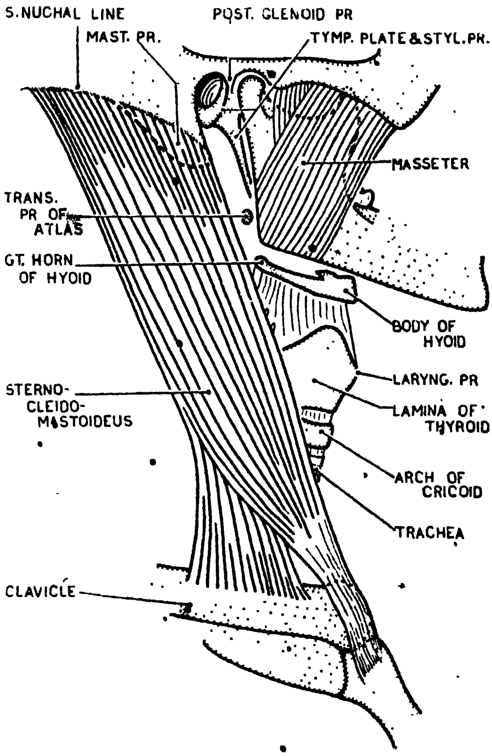


FIG. 673. The Sterno-mastoid and the side of the neck.

overflow it from above; but only three structures cross it superficially. They are: (1) the two main tributaries of the *common facial vein,* (2) the *great auricular nerve,* and (3) the *cervical branch of the facial nerve.* As these are not of great importance, the posterior belly may be exposed freely and without risk of doing damage. (*Figs. 627, 628.*)

Passing deep to the posterior belly of

the Digastric and thereby placing it in a commanding or key position are 3 great vessels, the last 3 cranial nerves, and the sympathetic trunk. In fact, *all structures in the carotid triangle that reach to higher levels pass deep to the posterior belly of the Digastric* (and to the Stylohyoid).

General Disposition of the Vessels and Nerves. The internal jugular vein, and the internal and external carotid arteries ascend side by side deep to the posterior belly. The vein is sheltered by the anterior border of the Sterno-mastoid and comes into view only when this is retracted. Nerves X, XI and XII, which are approximately equal in size, descend together from the skull and separate at or just above the lower border of the Digastric; nerve XI passes downwards and backwards superficial (or deep) to the internal jugular vein; nerve XII curves forwards superficial to the arteries. Both nerves are solely motor and both are in danger Nerve X lies deeply and descends vertically between the great vein and the great arterial trunk.

Identify the Nerves and Vessels in the Carotid Triangle in the order in which they are described below.

The Nerves. The spinal part of the Accessory Nerve (XI), supplies the Sterno-mastoid and Trapezius and therefore courses backwards. It appears from under cover of the Digastric, between the internal jugular vein and internal carotid artery. It crosses the internal jugular vein, which separates it from the transverse process of the atlas, and disappears into the deep surface of the Sterno-mastoid from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches below the tip of the mastoid process. Here lymph glands surround it. The sterno-mastoid branch of the occipital artery accompanies it.

On everting the anterior border of the Sterno-mastoid the accessory nerve can readily be found at this $1\frac{1}{2}''$ to $2\frac{1}{2}''$ point, and traced upwards to the Digastric where it meets nerve XII. Commonly, however, (58 of 197 specimens) the nerve crosses behind the internal jugular vein and lies in contact with the transverse process of the atlas.

The Hypoglossal Nerve (*fig. 674*) appears from under cover of the Digastric in contact with the accessory nerve or

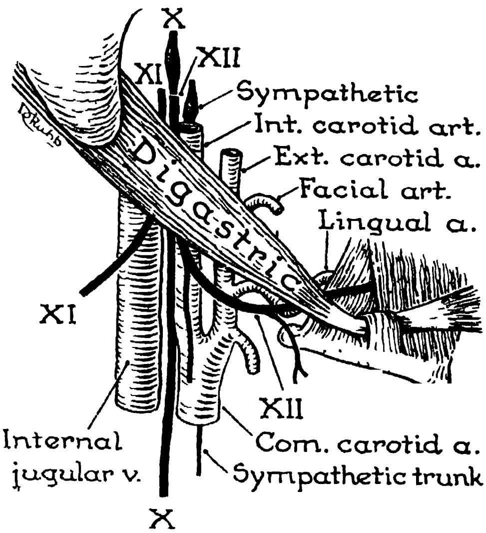


Fig. 674. The posterior belly of the Digastric in its key position. All structures, except three, passing to higher levels pass deep to it.

just medial to it It is the motor nerve to the tongue, so it courses forwards.

In embryonic life it looped down to a lower level, but later it was dragged upwards in front of the "*arterial plane*" till the occipital branch of the external carotid artery arrested its upward course. Therefore, in the adult it is found curving forwards superficial to every artery it meets; namely, the internal carotid, external carotid, and lingual arteries always, and commonly to the superior thyroid and facial arteries, but never deep to these

branches or they would arrest its ascent. It passes under cover of the posterior belly of the Digastric a second time and so enters the digastric triangle, where it crosses superficial to the lingual artery a second time. The latter separates it from the Middle Constrictor. Later it will be seen to disappear between the Hyoglossus and the Mylohyoid.

The hypoglossal nerve is most readily found just above the posterior end of the greater cornu of the hyoid bone, and from here traced backwards. When cleaning it keep to its upper border lest you damage two branches that spring from its lower or convex border.

Ansa Hypoglossi (*fig. 668*). As the hypoglossal nerve is curving round the occipital artery it gives off its *descending branch*, and the occipital artery gives off its *sterno-mastoid branch*. The sterno-mastoid branch of the occipital artery follows the accessory nerve to the Sterno-mastoid. The descendens hypoglossi nerve, which is composed of fibers picked up from nerve C. 1, traverses the carotid triangle in front of the internal and common carotid arteries. It is either in front of the carotid sheath or else embedded in the wall of the sheath. Near the intermediate tendon of the Omo-hyoid it joins the *descending branch of nerves C. 2 and 3* to form a loop, the *ansa hypoglossi*. This descending cervical nerve necessarily crosses the internal jugular vein: it does so either on its medial or lateral side.

Distribution. From the ansa hypoglossi branches pass to each of the 3 long infrahyoid muscles, one going to the upper and one to the lower part of each; the branch to the lower belly of the Omo-hyoid runs along its intermediate tendon. The Thyro-hyoid (i.e., the short infrahyoid muscle) receives a special branch from nerve C. 1, via the hypoglossal nerve. The nerves to the four infrahyoid muscles, therefore, are ultimately derived from cervical segments 1, 2, and 3. They pass between the superficial and deep layers of muscles, and enter them on their opposed surfaces or at their lateral borders. (See also p. 717.)

THE VAGUS NERVE (*figs. 674, 675*). To find the vagus, case the accessory

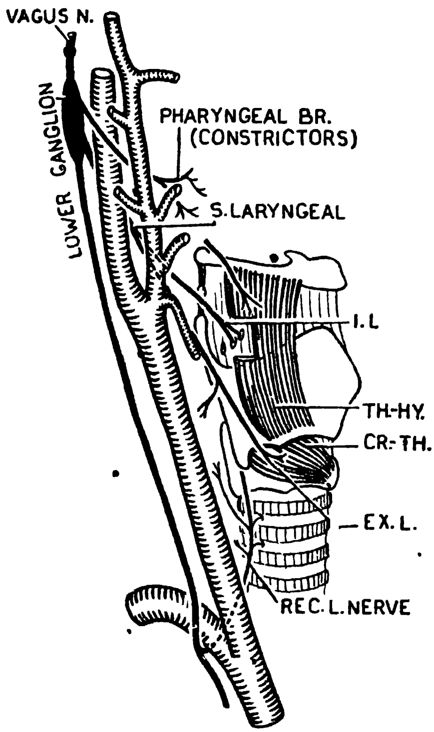


FIG 675 The pharyngeal and laryngeal branches of the vagus.

nerve and the internal jugular vein laterally, and the hypoglossal nerve and the internal carotid artery medially; then pick up the *vagus* or *X cranial nerve*, which runs vertically in the posterior groove between the internal jugular vein and the great arterial trunk, within the carotid sheath.

The last nerves to be sought are the two terminal branches of the superior laryngeal branch of the vagus, called the

internal laryngeal nerve, which is sensory, and the *external laryngeal nerve*, which is mainly motor.

The Internal Laryngeal Nerve is easily found where it pierces the thyro-hyoid membrane a little in front of the superior cornu of the thyroid cartilage, deep, of course, to the posterior border of the Thyro-hyoid. It runs along the upper border of the Inferior Constrictor and is accompanied by the superior laryngeal branches of the superior thyroid artery and vein, which pierce with it and lie below it—as, from a consideration of their origins, would be expected. It is sensory to the larynx above the level of the vocal cords. It may be followed backwards deep to the ext. and int. carotid arteries to the point where the ext. laryngeal nerve arises.

The External Laryngeal Nerve, loosely bound to the superior thyroid artery, descends obliquely between the fascia covering the Inferior Constrictor and the carotid sheath, (which should be retracted) and disappears deep to the Omohyoid. Later it will be followed to the Crico-thyroid or tensor muscle of the vocal cord.

The Crico-thyroid is morphologically a detached portion of the Inferior Constrictor. This explains why the external laryngeal nerve sends twigs to the Inferior Constrictor before piercing it to end in the Crico-thyroid. To get to the Crico-thyroid the nerve must pass deep to the attachment of the Sterno-thyroid to the oblique line on the thyroid cartilage —so must the superior thyroid artery. Indeed, the upper pole of the thyroid gland (depending upon its size) pushes the sup. thyroid art. either nearly to or against the ext. laryngeal nerve. Hence, the nerve is liable to be damaged in goitre operations with resulting weakness of the voice.

The Arteries (*fig. 676*). The arteries contained *in the carotid triangle* are parts of the common, internal, and external carotid arteries and the stems of most of the six collateral branches of the external carotid artery.

The Common Carotid Artery appears from under cover of the Omo-hyoid, ascends through the carotid triangle to the level of the upper border of the thyroid cartilage where it ends by dividing into two terminal branches of nearly equal size, the *internal* and *external carotid arteries*. These two ascend side by side, the internal artery being postero-lateral, the external artery being antero-medial, and both pass deep to the posterior belly of the Digastric—the external carotid artery to enter the parotid gland; the internal caroti dartery to pass deep to the parotid gland and styloid process.

The common and internal carotid arteries give off no collateral branches in the neck; so, it falls to the external carotid, assisted by the inferior thyroid artery, to supply the "cervical viscera".

The External Carotid Artery extends from the upper border of the thyroid cartilage to the neck of the mandible where it divides into 2 terminal branches, the *superficial temporal* and (internal) *maxillary arteries*. In its short course before entering the parotid gland it is applied to the Inferior and Middle Constrictors. Its 6 collateral branches radiate from it in the neighborhood of the posterior belly of the Digastric to reach the parts they supply. Of these, three arise from its anterior aspect close together below the Digastric. They are the *superior thyroid, lingual*, and *facial* (external maxillary) *arteries*. Now, this is their order of origin because the first has to descend to reach the thyroid gland, the second has to pass forwards to reach the tongue, and the third has to ascend to

reach the face. In this mobile part of the body all three take sinuous courses. The first is applied to the Inferior Constrictor, the second to the Middle Constrictor, the third to the Middle and Superior Constrictors; this is rendered apparent by superimposing fig. 670 on on fig. 669, which are drawn to scale.

The Superior Thyroid Artery arises at the bifurcation. Applied to the Inferior

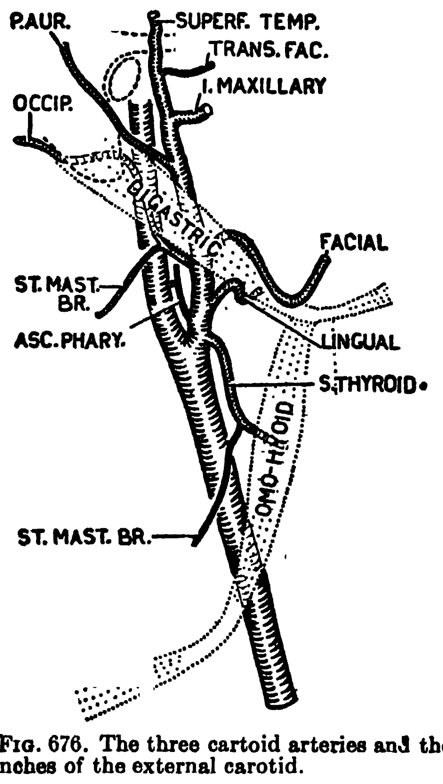


FIG. 676. The three cartoid arteries and the branches of the external carotid.

Constrictor, it must pass deep to the three long infrahyoid muscles ("Rectus Cervicis") in order to reach the thyroid gland. The upper pole of the gland forces this artery into the angle between the attachments of the Sternothyroid and Inferior Constrictor to the oblique line on the lamina of the thyroid cartilage, and therefore against the important external laryngeal nerve.

Its *branches* are: (a) an infrahyoid twig which runs below the hyoid bone; (b) a superior laryngeal branch, which pierces the thyro-hyoid membrane below the internal laryngeal nerve and supplies the larynx; (c) a crico-thyroid branch, which passes either superficial or deep to the Sternothyroid, crosses the Crico-thyroid muscle and ligament, anastomoses with its fellow, and sends a branch through the ligament into the larynx; (d) a sternomastoid branch, which follows the Omohyoid across the carotid sheath to the Sterno-mastoid, and (e) three end branches. Of the latter, one ramifies on the lateral surface of the thyroid gland; one on the medial surface; and one runs along the medial border to the isthmus where it anastomoses with its fellow.

The Lingual Artery, applied to the Middle Constrictor, loops upwards and forwards and, passing deep to the posterior belly of the Digastric, leaves the carotid triangle, and enters the digastric triangle where it at once passes deep to the Hyoglossus. The hypoglossal nerve looping downwards and forwards crosses it superficially twice—once in the carotid triangle and once in the digastric triangle (*p. 743*).

In 20% of 211 specimens the lingual and facial arteries spring from a common linguo-facial stem.

The Facial (External Maxillary) Artery steers a course for a point on the lower border of the jaw just in front of the Masseter. It is, however, deflected from the straight path by the posterior belly of the Digastric, which passes deep to the ramus of the jaw and carries the artery upwards before it. Hence the "∾" shaped course of the artery. The Middle and Superior Constrictors lie medial to the 1st or cervical loop of the artery, the Sup. Constrictor separating it from the tonsil (*fig. 720*). The Digastric, Stylo-

hyoid, and submandibular salivary gland occupy the concavity of this loop and the Medial Pterygoid lies laterally. Then, to enter the face it pierces the deep fascia of the neck and turns round the lower border of the jaw.

The *branches* from the cervical part are: *tonsillar, ascending palatine, glandular* (to the submandibular gland), and *submental.*

Its companion vein, the *anterior facial vein*, is not a close companion, because it takes a straighter and more superficial course, and is separated from the artery by the submandibular gland, Stylo-hyoid, and Digastric (*fig. 628*).

The Ascending Pharyngeal Artery (best seen when the pharynx is being dissected) arises from the deep aspect of the external carotid artery near its origin, and ascends on the Inferior, Middle, and Superior Constrictors as far as the base of the skull. The internal carotid artery is its lateral companion.

It supplies the pharynx, soft palate, tube, and meninges. The meningeal twigs traverse the hypoglossal, jugular, and lacerate foramina, and a tympanic twig follows the tympanic branch of the glosso-pharyngeal nerve.

The Occipital and Posterior Auricular Arteries follow the lower and upper borders of the Digastric backwards, and therefore cross the internal carotid artery, the last three cranial nerves, and the internal jugular vein. The mastoid then separates them. They end in the scalp and auricle.

The occipital artery occupies the groove on the mastoid bone medial to the groove for the Digastric, and therefore passes deep to the Digastric, to the mastoid process, and to the three muscles inserted into it. It then crosses the Superior Oblique and Semispinalis Capitis and, joining the greater occipital n., pierces the Trapezius an inch infero-lateral to the inion and ends in the scalp.

A sterno-mastoid branch follows the accessory nerve to the Sterno-mastoid. *Meningeal twigs* pass through the mastoid and parietal foramina. A *descending branch* anastomoses on both surfaces of the Semispinalis Capitis with the transverse and deep cervical arteries.

The posterior auricular artery generally arises at or above the upper border of the Digastric, that is, within the parotid region. It follows this border to the mastoid bone, crosses it superficially, and then ascends behind the auricle to the scalp. As it crosses the mastoid, it lies deep to the Auricularis Posterior and in company with the posterior auricular branch of the facial nerve.

Its *branches*, in addition to the obvious ones to the muscles, parotid, and scalp, are two of importance: (1) the *stylomastoid branch*, which follows the facial nerve through the facial canal to anastomose with the petrosal branch of the middle meningeal artery (and with the other arteries to the ear from the int. auditory, int. carotid, and int. maxillary, and ascending pharyngeal arteries), and (2) *auricular branches*, which supply the medial surface of the auricle and, by piercing the cartilage of the ear or turning round the helix, anastomose with branches of the superficial temporal artery and supply the lateral surface.

The Veins (*figs. 628, 711*). The *superior thyroid, lingual*, and *anterior facial* (the companion of the facial artery) *veins* as well as a *middle thyroid vein* cross superficial to the carotid arteries and end in the internal jugular vein. The anterior facial vein does so at the level of the hyoid bone after being joined by a branch of the posterior facial vein to form the *common facial vein.* The *pharyngeal plexus* is drained by several

pharyngeal veins which enter the internal jugular vein both above and below the Digastric. The *occipital vein* partly ends in the internal jugular vein and partly in the posterior vertebral plexus. The *posterior auricular vein* joins a branch of the posterior facial vein to form the *external jugular vein* (*fig. 711*).

Axiom. (a) Arteries running posteriorly cross superficial to the internal jugular vein: viz., the sterno-mastoid branch of the superior thyroid and of the occipital artery, and the occipital and the posterior auricular arteries. (b) Veins running posteriorly cross superficial to the great arteries: viz., the anterior jugular, middle thyroid, superior thyroid, lingual, and common facial veins.

The Digastric Triangle

The Boundaries of the digastric triangle are the two bellies of the Digastric and the lower border of the jaw. The anterior belly separates this triangle from the submental triangle; the posterior belly separates it from the carotid triangle; and a broad band of fascia, stretching from the styloid process to the posterior border of the ramus of the mandible, and hence called the *stylo-mandibular ligament*, separates it from the parotid region behind.

For practical purposes the triangle may be regarded as extending upwards deep to the body of the jaw as far as the origin of the Mylo-hyoid and, behind this, deep to the insertion of the Medial Pterygoid into the ramus of the jaw. This upward extension of the digastric triangle is known as the *submandibular region.*

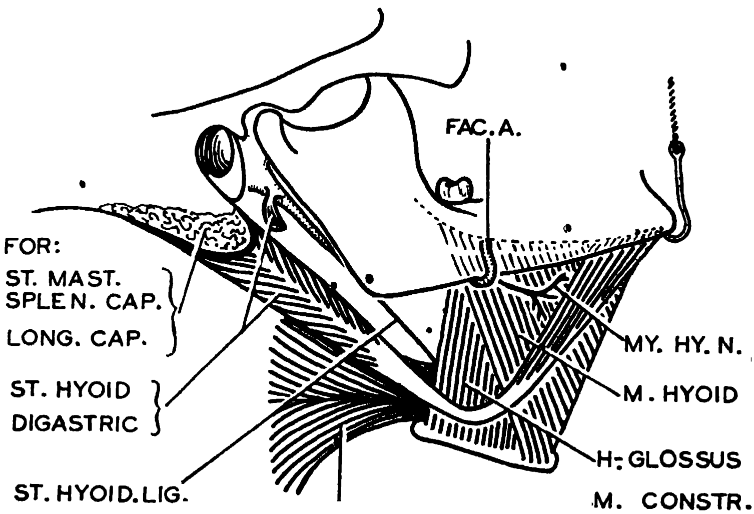


FIG. 677. The floor of the digastric triangle.

THE FLOOR of the triangle is formed by portions of 3 flat muscles—*Mylohyoid, Hyoglossus,* and *Middle Constrictor*—which lie on successively deeper planes (*fig. 677*).

The Mylohyoid arises from the mylohyoid line, which extends diagonally across the entire length of the medial surface of the body of the jaw. This line begins at the symphysis, between the digastric fossa and the genial tubercle, and ends below the third molar tooth. It is all but continuous with a ridge of bone that strengthens the coronoid process

(*fig. 690*). The mylohyoid line separates the fossa for the sublingual salivary gland antero-superiorly from the fossa for the submandibular salivary gland postero-inferiorly. The fibers of the Mylohyoid run infero-medially to be attached to the body of the hyoid bone and to a median raphé that extends from the hyoid bone to the symphysis menti. It thus constitutes with its fellow a diaphragma oris. Its posterior border is oblique and free.

The Hyoglossus arises from the whole length of the greater cornu of the hyoid (and slightly from its body). Its fibers run upwards and forwards to be attached to the side of the tongue where they interdigitate with fibers of the Styloglossus. It is rhomboidal with free anterior and posterior borders. It is overlapped by the Mylohyoid, and in turn it overlaps the Middle Constrictor

The Middle Constrictor has an angular origin from the whole length of the greater cornu, lesser cornu, and lowest part of the stylohyoid lig deep to the Hyoglossus

THE CONTENTS. (*figs. 678, 692*) of the digastric triangle are (1) the submandibular salivary and lymph glands, (2) the nerve to the Mylohyoid and anterior belly of the Digastric, (3) the hypoglossal nerve, (4) the lingual and (5) facial arteries, and (6) the anterior facial vein.

The Submandibular Gland occupies a V-shaped pocket of deep cervical fascia. This fascia splits below to enclose the gland; the superficial layer ascends to the lower border of the jaw; the deep layer covers the floor of the region and ascends to the mylohyoid line. The pocket is, therefore, closed above by the medial surface of the jaw. The gland fills the triangle to overflowing. Thus: It conceals parts of the Mylohyoid, Hyoglossus, Middle Constrictor, and both bellies of the Digastric. It extends backwards to the parotid salivary gland, only the stylomandibular ligament intervening. It extends upwards between the body of the jaw and the Mylohyoid, and between the insertion of the Medial Pterygoid and the Superior Constrictor. Later it will be seen to send a process round the free posterior border of the Mylohyoid along the floor of the mouth as far as the sublingual salivary gland. The posterior free edge of the Mylohyoid may, indeed, be said to indent the gland and so to divide it into a superficial and a deep part, precisely as the free lateral edge of the Levator Palpebrae indents and divides the lacrimal gland into superficial and deep parts.

The Anterior Facial Vein crosses superficial to the submandibular gland. When the lower border of the gland is raised and the intermediate tendon of the Digastric pulled either up or down, the *hypoglossal nerve* can be traced forwards superficial to the lingual artery and across the Hyoglossus to the posterior border of the Mylohyoid, deep to which it disappears. And, the *lingual artery* can be traced forwards on the Middle Constrictor to the posterior border of the Hyoglossus deep to which it disappears. When the anterior end of the gland is raised and drawn backwards the branch of the inferior dental (alveolar) *nerve to the Mylohyoid* and anterior belly of the Digastric is seen, accompanied by the submental branch of the facial artery. It may be traced backwards on the inner surface of the jaw to the interval between the anterior free border of the Medial Pterygoid and the ramus, and forwards to the two muscles in which it ends.

When the anterior facial vein is freed from the superficial surface of the submandibular gland, and the facial artery from the deep surface, the superficial or cervical part of the gland

can be severed from the deep or oral part and from the duct and removed. An excellent view of the region is then obtained.

The Facial (*Ext. maxillary*) *Artery.* The sinuous course taken by the facial artery is seen to be due to the fact that the Digastric, Stylo-hyoid, and submandibular gland,——all 3 of which separate the artery from the anterior facial vein,——drag it upwards between the Medial Pterygoid and the region of the tonsil bed (*fig. 730*).

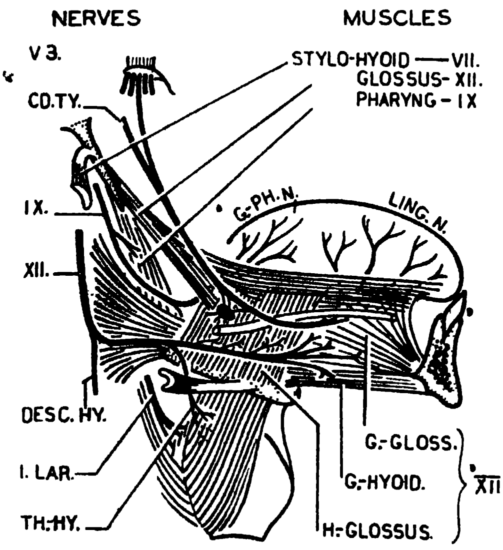


FIG. 678. The digastric triangle and submandibular region.

In the neck the *branches* of the facial artery are: submental, glandular, ascending palatine, and tonsillar.

The *submental artery* follows the end portion of the mylohyoid nerve, sends twigs through the Mylohyoid to the floor of the mouth, and then turns around the lower border of the jaw and ends in the lower lip.

Glandular branches supply the submandibular salivary gland.

The *ascending palatine* and *tonsillar branches* arise at the summit of the bend and, after passing one on each side of the Styloglossus, ascend on the Superior Constrictor; the tonsillar branches pierce the S. Constrictor; the ascending palatine branch turns over the upper border of the S. Constrictor and descends with the Levator Palati to supply the pharynx, soft palate, and tonsil bed.

To Display the Side of the Tongue (*figs. 678, 723*). It requires skill and a sharp knife to display at a higher level (a) the insertion of the Styloglossus interlocking with the Hyoglossus at the upper limit of the space, and (b) the glosso-pharyngeal (IX) nerve following the upper border of the M. Constrictor and disappearing deep to the Hyoglossus ½″ above the lingual artery; and (c) to sever the Hyoglossus from the greater horn in order to display the *2nd part of the lingual artery*. This artery crosses the origin of the Middle Constrictor, the stylo-hyoid ligament, and the Genioglossus, and sends one or two twigs (dorsalès linguae arteries) to the dorsum of the tongue and tonsil region. These will be considered when the inside of the mouth and pharynx are studied (*p. 743*).

Parts seen to better advantage from the inside of the mouth may be exposed on one side now.

Thus, cut the inverted sling of fascia that holds down the intermediate tendon of the Digastric; detach the Stylo-hyoid from the hyoid; and throw both muscles upwards. Detach the Mylo-hyoid from the body of the hyoid and from its fellow at the median raphé and throw it upwards.

The *hypoglossal* and *lingual nerves* with the *submandibular duct* between them are displayed crossing the Hyoglossus, and the 3rd part of the *lingual artery* is seen ascending at its free anterior border.

The *Genio-hyoid* is displayed inserted into the body of the hyoid almost in continuity with the Sterno-hyoid and Omo-

hyoid, but it is twice as thick as they are, and it tapers as it ascends, in contact with its fellow, to be attached to the lower genial tubercle. Nerve XII conveys to it fibers from C. 1.

Reflect the Geniohyoid and see the hypoglossal and lingual nerves plunging into the tongue (*fig. 723*).

THE ROOT OF THE NECK

The Great Vessels. General Dispositions. The right common carotid and subclavian arteries arise from the innominate artery behind the upper part of the right sterno-clavicular joint. The left common carotid and subclavian arteries arise from the aortic arch, and after a course of an inch enter the neck by passing behind the left sterno-clavicular joint. On both sides, two infrahyoid muscles intervene between the arteries and the joint, and on the left side there is the left innominate vein as well. On both sides, the common carotid artery lies in front of the subclavian artery at the entrance to the neck and it ends in the carotid triangle at the upper border of the thyroid cartilage by dividing into two terminal branches, the internal and external carotid arteries. It has no collateral branches.

The Subclavian Artery arches over the cervical pleura and first rib, and it becomes the axillary artery at the lower border of this rib. It will be recalled that the axillary artery passes a finger's breadth medial to the tip of the coracoid.

Surface Anatomy. A curved line running from the sterno-clavicular joint to a point a finger's breadth medial to the tip of the coracoid, and rising an inch above the clavicle, marks the course of the subclavian artery and it may be observed that it crosses the clavicle near its midpoint.

The subclavian artery is divided into three parts—1st, 2nd, and 3rd—by the Scalenus Anterior which crosses in front of the 2nd part and separates it from its vein. The *subclavian vein* has only two parts. These correspond to the 3rd and 2nd parts of the artery; the beginning of the innominate vein substitutes for the 1st part. The reason is that the subclavian vein lies within the concavity of its companion artery, whereas the internal jugular vein lies lateral to its com-

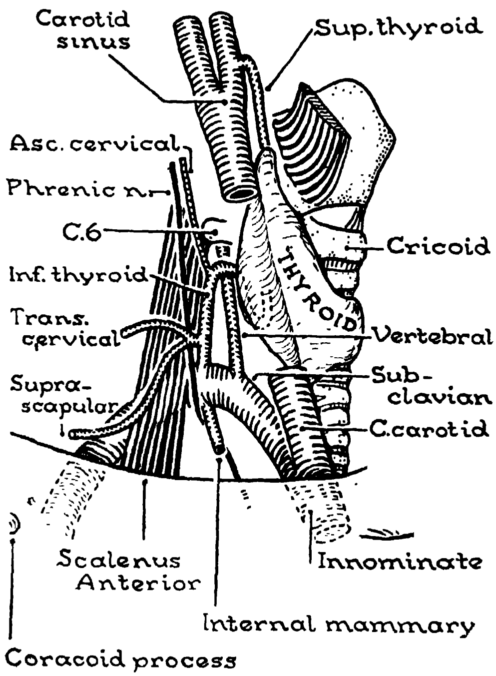


FIG. 679. The arteries at the root of the neck.

panion, the common carotid artery, and so has to cross the 1st part of the subclavian artery in order to effect the union known as the innominate vein. The termination of the internal jugular vein, then, crosses and largely conceals the 1st part of the subclavian artery and the stems of the branches arising from it. It is, of course, legitimate to think in terms of the "1st part of the subclavian vein" and, when tributaries are under

consideration, it is helpful to do so; but we must speak and write of the "beginning of the innominate vein".

"The Triangle of the Vertebral Artery" (*figs. 679, 680*). It will simplify further study of the great vessels and of the region as a whole, and it will save much repetition if a digression is made in order to examine with care a triangle with the following boundaries:

Base—1st part of the subclavian artery;
Lateral side—Scalenus Anterior;
Medial side—Longus Cervicis;

uppermost part of the cervical pleura which rises to the neck of the 1st rib.

THE CONTENTS are: (A) *The vertebral artery*, which ascends near the medial border of the triangle (Longus Cervicis) from base to apex and there enters the foramen transversarium of vertebra C. 6. (B) *The vertebral vein*, which descends in front of the vertebral artery, crosses the subclavian artery, and ends in the innominate vein. (C) *The inferior thyroid artery*, which ascends near the lateral border of the triangle (Scalenus Anterior),

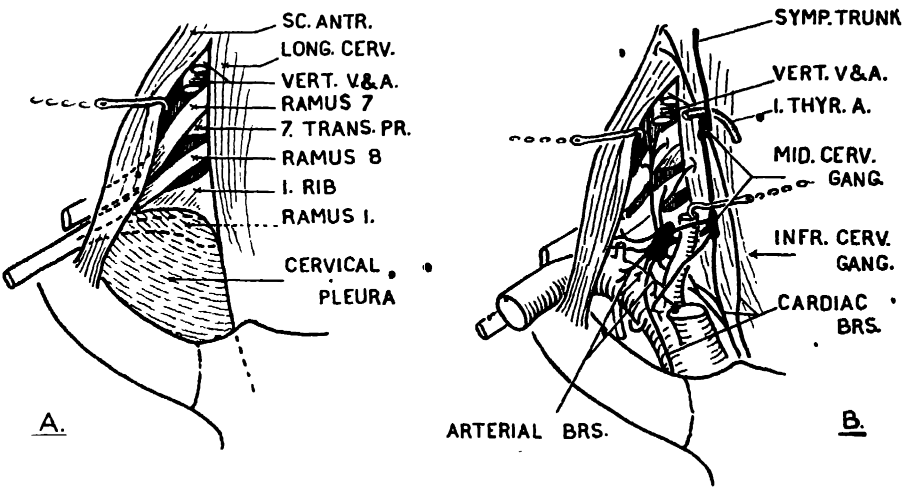


FIG. 680. "The triangle of the vertebral artery."

Apex—the anterior tubercle of the 6th cervical transverse process.

In cases where the thyroid gland is enlarged, the Longus Cervicis is concealed. To obtain a view of the triangle, the common carotid artery should be divided low down and thrown aside and the internal jugular vein should be held laterally (*figs. 702, 629*).

The Posterior Wall of the triangle descends below the neck of the 1st rib. It therefore includes the transverse process of C. 7, the anterior ramus of nerve C. 8 which runs laterally above the neck of the 1st rib, the neck of the 1st rib, and the

arches medially in front of the vertebral vessels and therefore falls short of the apex. (D) *The gangliónated sympathetic trunk*, which, followed downwards, usually splits to encircle (1) first the inferior thyroid artery, (2) secondly the vertebral artery, and (3) thirdly the subclavian artery. On the sympathetic trunk there are these 3 ganglia: (a) in front of the inferior thyroid artery lies a small ganglion, which is a detached part of the middle cervical ganglion; (b) in front of the vertebral artery lies the middle cervical ganglion; and (c) behind the origin of the vertebral artery and in front of the

anterior ramus of C. 8 is the inferior cervical (sympathetic) ganglion. The inferior ganglion is large and bristling with gray rami communicantes and is commonly continuous with ganglion Th. 1 which rises in front of the neck to the first rib.

Ascending in front of the triangle are:
(a) The carotid sheath and contents.
(b) The phrenic nerve.

Arching in front of the triangle are:
(c) The inferior thyroid artery.
(d) The thoracic or right lymph duct.

The *carotid sheath* and its 3 contents overlap the sides, base, and apex of the triangle, their precise positions depending upon the size of the thyroid gland which thrusts them laterally away from the "cervical viscera". Thus, the *common carotid artery* is often forced off the Longus Cervicis on to the front of the vertebral vessels, and the *internal jugular vein* on to the front of the Scalenus Anterior. The *vagus nerve* descends between them. All three either cross in front of, or lie in front of, the 1st part of the subclavian artery. [Thus, the right and left common carotid arteries and the left vagus lie in front of the respective subclavian arteries; the right and left internal jugular veins and the right vagus cross in front of the respective subclavian arteries.]

The *phrenic nerve*, after descending in front of the Scalenus Anterior, slips off the anterior border of this muscle on to the subclavian artery. Though, strictly speaking, the nerve may not be within the triangle its importance justifies its claim to be considered with it.

The *inferior thyroid artery* and the *thoracic* (or *right lymph*) *duct* arch between the vertebral vessels and the carotid sheath. The artery arches *medially* below the 6th transverse process; the duct arches *laterally* at the 7th transverse process.

LANDMARKS. The anterior tubercle of the transverse process of the 6th cervical vertebra is a deep landmark of importance. Unlike other anterior tubercles it has an independent center of ossification. This and the absence of a tubercle on the 7th vertebra render it unusually prominent. *Events:* (1) At this level lies the cricoid cartilage and therefore the junction of the pharynx with esophagus, and of larynx with trachea. (2) Here is the intermediate tendon of the Omohyoid and therefore the boundary between the muscular and carotid triangles. (3) The common carotid artery passes in front of the tubercle and may be compressed against it. Hence, it is called the carotid tubercle. (4) The vertebral artery disappears into the 6th foramen transversarium and therefore passes behind the tubercle. (5) The tubercle is the apex of "the triangle of the vertebral artery" and the Scalenus Anterior and Longus Cervicis ascend to be attached to it.

The Subclavian Artery (cont'd. from page 666). The course and relations of the right subclavian artery and of the cervical part of the left subclavian arteries are almost identical—but not quite.

Below are cervical pleura and 1st rib.

Behind are cervical pleura and the insertion of the Scalenus Medius into the 1st rib, but the lowest trunk (C. 8 and Th. 1) of the brachial plexus grooves the 1st rib and therefore intervenes.

Antero-inferiorly is the subclavian vein and its continuation,—i.e., the beginning of the innominate vein—the phrenic, vagus, certain cardiac nerves, and the ansa subclavii intervening.

Anterior Relations. The 1st part of the subclavian artery lies medial to the Scalenus Anterior and is covered anteriorly not only by Sternomastoid, sternal end of the clavicle, transverse part of the anterior jugular vein

which runs just above the clavicle, Sternohyoid and Sternothyroid, but also deep to these by the internal jugular vein which is accompanied by the phrenic nerve (postero-laterally), vertebral vein (posteriorly), and vagus nerve (posteromedially).

The *right phrenic nerve* tends to cling to the anterior border of the Scalenus Anterior. For embryological reasons, the *right recurrent laryngeal nerve* arises from the vagus while it is crossing the subclavian artery and it recurs below and behind the artery. The *left vagus nerve* descends into the thorax in the angle between the left subclavian and left common carotid arteries. On the left side the *thoracic duct*, on the right side the *right lymph duct*, are immediate anterior relations. On *both sides* a thread, the *ansa subclavii*, which connects the middle with the inferior cervical sympathetic ganglion, loops in front, below, and behind the artery. Cardiac branches of the vagus and sympathetic cross both in front of the artery and behind it.

The 2nd part is separated from its vein by the Scalenus Anterior.

The 3rd part is described on page 595.

Branches. The branches of the subclavian artery generally arise from the 1st part only; so, at their origin they are concealed by the internal jugular or the innominate vein; and the cervical pleura lies behind them. They are named:

1. Vertebral.
2. Thyro-cervical trunk:
   - Inferior thyroid.
     - ascending cervical.
     - oesophageal and tracheal.
     - pharyngeal and laryngeal.
     - thyroid.
   - Transverse cervical.
   - Suprascapular.
3. Internal mammary.
4. Costo-cervical trunk:
   - Deep cervical.
   - Superior intercostal.
     - 1st posterior intercostal.
     - 2nd posterior intercostal.

The Vertebral Artery ascends vertically along the lateral border of the Longus Cervicis to the level of the cricoid cartilage and there, in the angle between the Scalenus Anterior and Longus Cervicis, enters the foramen transversarium of the sixth cervical vertebra. *In front* lies the carotid sheath, but crossing between it and the sheath are the thoracic (or right lymph) duct and the inferior thyroid artery. *Behind* are pleura up to the neck of the 1st rib, inferior cervical ganglion, anterior nerve ramus C. 8, and the seventh cervical transverse process. Gray rami communicantes from the inferior cervical ganglion to nerves C. 4, 5, and 6 and to the cerebral vessels accompany it into the foramen.

The two vertebral and two internal carotid arteries alone convey blood to the brain.

The Thyro-cervical Trunk arises from the subclavian artery between the vagus and phrenic nerves. The trunk has no length but at once ends as three branches. Of these, (a) and (b) the *Suprascapular* and *Transverse Cervical Arteries* run laterally across the Scalenus Anterior to the posterior triangle and "clamp down" the phrenic nerve—prevertebral fascia intervening. The suprascapular artery, being the lower, courses behind the clavicle; the transverse cervical artery courses behind the Sterno-mastoid.

(c) *The Inferior Thyroid Artery* takes an S-shaped course. It ascends first along the medial border of the Scalenus Anterior, then arches horizontally between vertebral vessels and carotid sheath (therefore below the carotid tubercle) and

either through, in front of, or behind the sympathetic trunk. It then descends towards the lower pole of the thyroid gland where it breaks up into an upper and a lower glandular branch. Later the recurrent nerve will be seen to pass either behind, between, or in front of the glandular branches (*fig. 683*).

The artery supplies the thyroid and parathyroid glands and sends branches to the trachea and oesophagus, pharynx and larynx. It is therefore a visceral artery. The laryngeal branch follows the recurrent nerve into the pharynx. It has also a large muscular branch, the *ascending cervical artery*, which arises at or near the summit of the "∾" and ascends on the Scalenus Anterior medial to the phrenic nerve and is apt to be mistaken for it.

The Internal Mammary Artery arises opposite the thyro-cervical trunk, descends on the pleura behind the subclavian vein, and is crossed either in front or behind by the phrenic nerve.

The Costo-cervical Trunk arises at or behind the border of the Scalenus Anterior, curves over the cervical pleura to the neck of the 1st rib, and there divides into two branches: (a) The *deep cervical branch* passes backwards between the neck of the 1st rib and the 7th cervical transverse process, and anastomoses with the descending branch of the occipital artery. (b) The *superior intercostal branch* descends between the sympathetic trunk medially and the branch from Th. 1 to the brachial plexus laterally, crosses in front of the necks of the 1st and 2nd ribs and supplies posterior intercostal arteries to the 1st and 2nd intercostal spaces.

Veins (*fig. 681*). The blood delivered by the 4 branches of the subclavian artery mostly returns to the innominate vein which substitutes for the 1st part of the subclavian vein. The *vertebral* and the *internal mammary veins* return directly. There are no thyro-cervical and costo-cervical venous trunks; but the veins corresponding to the five primary branches of the thyro-cervical and costo-cervical arterial trunks (see list, p. 669) behave thus: The *inferior thyroid veins* descend in front of the trachea to the innominate veins. The *transverse cervical* and *suprascapular veins* open into the external jugular vein, and so to the 3rd part of the subclavian vein. This is in keeping with the fact mentioned above (*p. 595*) namely, that the corresponding ar-

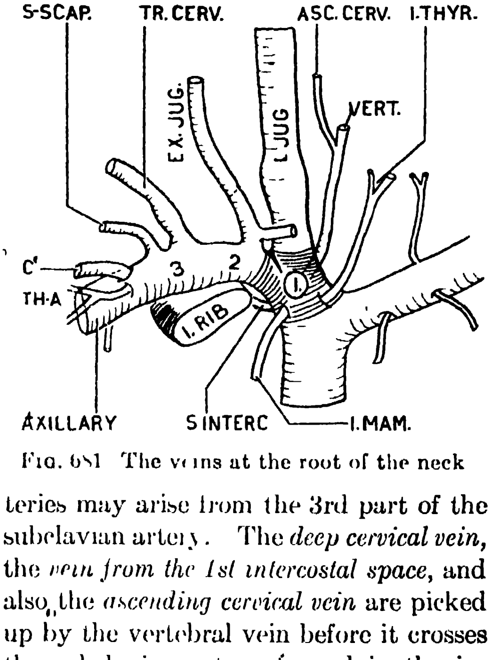


FIG. 681 The veins at the root of the neck

teries may arise from the 3rd part of the subclavian artery. The *deep cervical vein*, the *vein from the 1st intercostal space*, and also the *ascending cervical vein* are picked up by the vertebral vein before it crosses the subclavian artery to end in the innominate vein. (*See also fig. 711.*)

The internal jugular and subclavian veins each possess one double cusped valve. The internal jugular valve extends a finger's breadth or less above the clavicle. Below that there is a dilatation called the *inferior jugular bulb*. The subclavian valve is placed near the junction with the axillary vein.

The Phrenic Nerve arises from the

anterior ramus of C. 4 and receives twigs from C. 3 and C. 5 and gray rami communicantes. It starts deep to the prevertebral fascia (*fig.* 629) and, as its destination is the diaphragm, it has no vertically in naked contact with the obliquely placed Scalenus Anterior, crossing it from posterior to anterior border. It then crosses in front of the 1st part of the subclavian artery and enters the thorax by crossing the internal mammary artery (in front or behind). Thereafter, it descends on the pleura. (The right phrenic nerve commonly remains on the Scalenus Anterior until the subclavian artery is passed.)

In front of the phrenic nerve, but separated from it by the prevertebral fascia, are (1) the transverse cervical and suprascapular arteries, which clamp it down and prevent it from being confused with the vagus; (2) the end of the thoracic (or right lymph) duct; and (3) the internal jugular vein and the junction of the subclavian and innominate veins which largely cover it.

(Thoracic course, see p. 566.)

It is the sole *motor nerve* to its own half of the diaphragm (*fig. 303*): the fibers from C. 3 supply the anterior part, those from C. 4 the intermediate part, and those from C. 5 the hinder part. It also conveys *sensory fibers* to the central part of the diaphragm, the mediastinal pleura, and the pericardium, and it sends twigs to the i. v. cava, adrenal gland, and hepatic plexus.

Variations. The phrenic nerve rarely passes in front of the subclavian vein. The root from C. 3 may be derived from the ansa hypoglossi. The slender branch from C. 5 commonly travels via the nerve to the Subclavius and joins the phrenic nerve behind the 1st costal cartilage; it crosses in front of the subclavian vein—but it may cross behind it.

The Thoracic Duct enters the neck on the left side of the esophagus and at once, at the level of the C. 7, arches laterally and forwards on the cervical pleura. It opens into the angle between the left internal jugular and subclavian veins, which lies behind the sternal end of the clavicle, and is there guarded by a bicuspid valve. Its course is simple—it goes behind the 3 structures contained within the carotid sheath, and in front of "the plane of the subclavian artery and its branches", some or all of which it crosses anteriorly, depending on the extent of the arc it makes. Therefore, it crosses behind the vagus, which lies within the carotid sheath, and in front of the phrenic nerve, which is clamped down by the transverse cervical and suprascapular arteries.

To find the duct, you merely pull forwards the carotid sheath—nothing else—and with two pairs of blunt forceps tease the areolar or fatty-areolar tissue behind the sheath for a flattened, friable vessel curving laterally to open into the angle between the two veins. Its last half inch (i.e., beyond its last valve) may be distended with venous blood.

On each side there are three lymph trunks, the *internal jugular*, *subclavian*, and *broncho-mediastinal*, which open into the internal jugular, subclavian, and innominate veins respectively near the angle of union. On the left side, they may open into the thoracic duct; on the right side, they may unite to form a short stem (half-an-inch) called the *right lymph duct*. The first two follow the veins of the same names; the broncho-mediastinal duct is formed by the union of efferents from the tracheo-bronchial glands and the internal mammary glands. The tracheo-bronchial glands receive the efferents from the lungs; the internal mammary glands drain territory supplied

by the internal mammary artery, including the anterior abdominal wall, thoracic wall, mamma, mediastinum, and diaphragm, also the upper surface of the liver via the falciform ligament. These vessels contain lymph; the thoracic duct also contains digested fat (chyle).

The Thyroid Gland consists of a right and a left *lobe*, which are pointed above and rounded below and are connected with each other near their lower

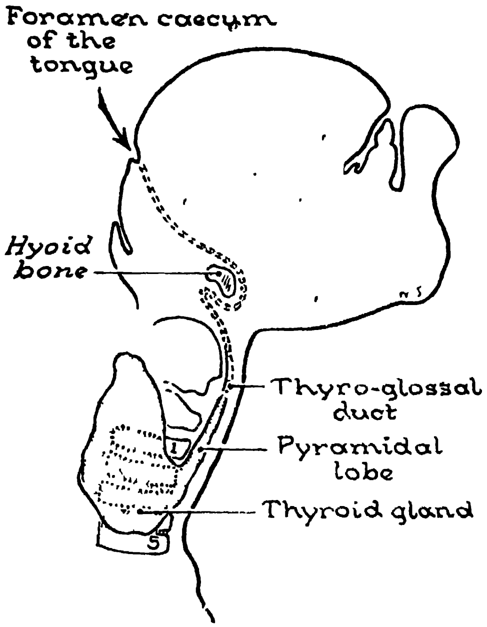


FIG. 682 The course of a developing thyroid gland (From data by J E Frazer.)

ends by a narrow *isthmus*; and, from the isthmus a finger-like process, the *pyramidal lobe*, commonly ascends near the median plane towards, or to, the hyoid bone.

Development. The mode of development (*fig. 682*) of the gland explains its relations. The thyroid gland arose as a median outgrowth of the pharynx between the anterior and posterior rudiments of the tongue. It grew downwards under cover of the "Rectus Cervicis" (*p. 654*), behind (? through) the developing hyoid bone, and in front of the thyroid and cricoid cartilages and upper rings of the trachea; and it spread out on the sides of the trachea into right and left lobes in much the same way as a large drop of candle grease might trickle down a candle, clinging to it. The foramen cecum of the tongue marks its site of origin; the pyramidal lobe when present indicates its course.

Recently it has been shown that each lobe is in part developed as an outgrowth or diverticulum from the ventral portion of the fourth pharyngeal or branchial pouch (Weller); the superior parathyroid gland is developed from the dorsal portion of the same pouch.

The isthmus ultimately crosses the (1), 2, 3, and (4) tracheal rings; and each lobe expands downwards on the side of the trachea, backwards on to the oesophagus, and upwards on to the pharynx and larynx; the upward expansion is, however, arrested by the attachment of the Sterno-thyroid to the oblique line of the thyroid cartilage. The gland clings closely to the "four visceral tubes" (*p. 654*) and forces the carotid sheath aside. When large it overflows laterally in front of the carotid sheath, and downwards retro-sternally in front of the great vessels and pleura. The upper pole overlies the Inferior Constrictor and Crico-thyroid.

The external laryngeal branch of the vagus is in contact with its upper pole and with the superior thyroid artery in the angle between the attachments of the Inferior Constrictor and Sterno-thyroid. The recurrent branch of the vagus is a medial relation as far as the lower border of the Inferior Constrictor, i.e., up to the level of the cricoid cartilage.

The thyroid gland, like the prostate gland and kidney, has a *capsule* proper and a loose *areolar sheath*. The vessels ramify on and in the gland, and the para-

thyroid glands lie on its posterior border between the capsule and sheath. When the isthmus is divided and raised, each lobe is seen to be bound to the crico-tracheal membrane by a dense fibrous or *ligamentous band.* Hence, the gland must follow the movements of the trachea. Along the band accessory arterial twigs pass from tracheal vessels to the gland. If the lobe is eased laterally and the band divided carefully, the *recurrent nerve* can be found ascending on the side of the trachea (just in front of the tracheo-oesophageal angle) to the back of the crico-thyroid joint where it disappears deep to the Inferior Constrictor. The nerve lies between layers of the sheath and passes either in front of, between, or behind the branches of the inferior thyroid artery (*fig. 683*); it sends twigs to the oesophagus, trachea, and thyroid gland.

Structure. Small pieces of thyroid gland, left for several hours in 75% hydrochloric acid, dissociate into small follicles or vesicles which are angular, round, or oval with an average length of 163μ (J. L. Jackson). The wall of each follicle consists of a single layer of low cubical cells; the cavity is filled with a semi-solid material called colloid which stores an iodine compound and stains red with eosin. The follicles are arranged in macroscopic clusters which are surrounded and held together by an areolar stroma continuous externally with the capsule of the gland. In this stroma run the larger blood vessels, lymph vessels, and nerves; in the reticular stroma which holds together the individual follicles the blood vessels and lymph vessels form very extensive capillary plexuses. No other organ, except perhaps the adrenal gland, is so vascular. The iodine compound is a hormone which is absorbed into the blood stream.

Function. The thyroid gland elaborates the hormone (thyroxine) which controls the rate of oxidation in the body. Marked hypofunction of the gland in childhood results in retarded skeletal growth, delayed epiphyseal union, and arrested sexual and mental development; this is called cretenism. Marked hypofunction of the gland in adult life results in an oedematous condition due to an albuminous (mucinous) substance accumulating subcutaneously, and hence called myxoedema. Hyperfunction increases the metabolic rate and the heart rate and is usually associated with nervous instability and loss of weight. In the variety of hyperthyroidism called Graves' disease (exophthalmic goitre) there is exophthalmos.

Vascular and Nerve Supply. Its *arteries* are the paired superior and inferior thyroid arteries, and the occasional median unpaired thyroidea ima. They anastomose freely. Of its *veins*, the superior thyroid vein follows the superior thyroid artery, crosses in front of the carotid artery to end in the internal jugular vein; the inferior thyroid vein (or veins) follows the thyroidea ima to the left innominate vein, and the middle thyroid vein on each side leaves the middle of the lateral border of the gland, crosses the common carotid artery to end in the internal jugular vein. *Lymph vessels* pass from extensive lymph plexuses to the deep cervical, pretracheal, and paratracheal glands. Perhaps a vessel passes directly to the right subclavian vein and another to the thoracic duct, without the intervention of a gland. *Nerves:* Sympathetic fibers leave the superior and middle cervical ganglia and are relayed via the superior and inferior thyroid arteries and middle thyroid vein and via the external and recurrent laryngeal nerves.

Anomalies. The isthmus may disap-

pear; the pyramidal lobe may persist; ectopic lobules may occur between the infrahyoid muscles; the thyroglossal duct may persist and open at the foramen cecum, or be broken up into one or more thyroglossal cysts. One or both inferior thyroid arteries are not uncommonly absent

The Parathyroid Glands (*fig. 720*) are yellowish-brown like a bumble bee, and they lie along the posterior border of the thyroid gland between its capsule and sheath. There are two glands on each side, an upper and a lower. The upper gland is elongated (6 mm.) and occupies a crack near the middle of the posterior border of the thyroid gland. The lower gland is flat and circular (5 mm.) and lies near the lower pole. A branch of the inferior thyroid artery supplies both glands, and twigs from the nerves to the thyroid enter them.

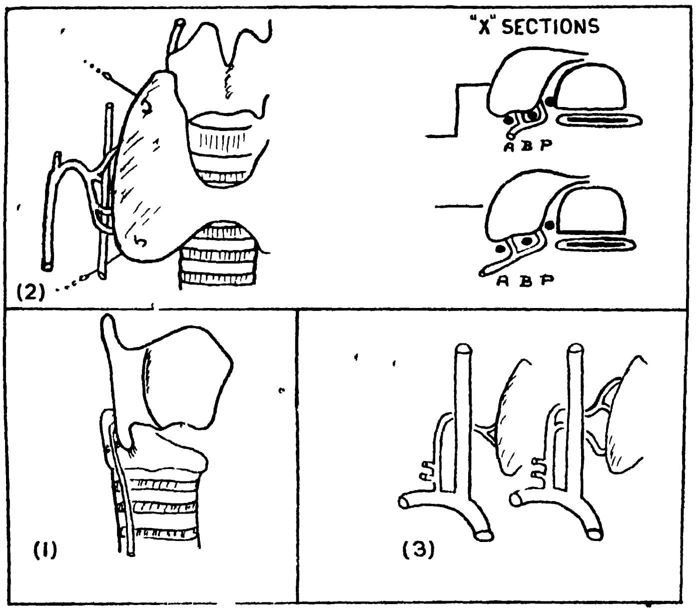


FIG. 683. Relation of the recurrent laryngeal nerve to:—(1) The upper end of the trachea, and to (2) the branches of the inferior thyroid artery; (a) entirely anterior in 8 of 98 cases; (b) between in 65; (p) entirely posterior in 25. (3) The infr. thyroid a. not uncommonly divides early—before crossing the common carotid a

Structure. The gland is composed of cells closely packed together in clumps or in cords. These cell aggregations are separated from one another by sinusoidal capillaries, and all is supported by a reticular framework. The cells are of two main types: principal and oxyphil. The principal cells are large and rounded and have clear cytoplasm and a vesicular nucleus. The oxyphil cells are somewhat larger and have an oxyphilic cytoplasm and a small compact nucleus; these cells too are in clumps but they do not appear until about the age of ten.

Function. The gland elaborates a hormone which controls the blood-calcium level. By analogy it may be said to act towards calcium much as haemoglobin acts towards oxygen, the parathyroid hormone in the circulating blood allowing the blood to take up more calcium than it otherwise could for distri-

bution to the tissues of the body. Removal of the parathyroid glands, or even a sufficiently low calcium diet, results in tetany, a condition characterised by symmetrical and painful spasms of the muscles of the extremities. This can be relieved immediately by injections of calcium in readily ionizable form. Hyperparathyroidism can be produced experimentally by injections of the hormone and it is encountered clinically in cases of parathyroid tumour. In this condition the blood attracts calcium with such avidity that calcium is drained from the bones—particularly from the trabeculae in the metaphyses of growing bones. The resorbed bone being replaced by soft connective tissue, fractures are common.

Development. The inferior gland, like the thymus, is developed from the third pharyngeal pouch and it follows the thymus to a lower level than the superior gland which, like the lobe of the thyroid gland, is developed from the fourth pouch. Hence, the inferior gland is sometimes called the parathymus, the upper, the parathyroid. The lower gland may follow the thymus gland for some distance below the thyroid gland—in man its position is quite variable.

The Trachea and Oesophagus begin where the larynx and pharynx end, which is at the cricoid cartilage in front of the sixth cervical vertebra, six inches from the incisor teeth. The trachea ends at the level of the sternal angle. If you measure from cricoid cartilage to sternal angle you will find the distance is $4\frac{1}{2}''$; this is the length of the trachea. The trachea occupies the median plane, except below where the aortic arch deflects it to the right. *Behind* it lies the oesophagus, but between the two there is enough areolar tissue to allow each to dilate and contract independently, cf., the bladder and rectum. Behind the cervical part of the oesophagus is the vertebral column, separated only by prevertebral fascia and the Longus Cervicis muscles. The fifteen or so C-shaped rings that keep the lumen of the trachea patent are absent behind where it is applied to the anterior wall of the oesophagus. Its outside diameters in the cadaver are about $\frac{3}{4}''$ by $\frac{4}{5}''$. *In front* of the cervical portion of the trachea are the structures in the median line of the neck *(p. 652)*. *On each side* is the common carotid artery, save where thyroid gland intervenes. The recurrent nerve ascends in the angle between the trachea

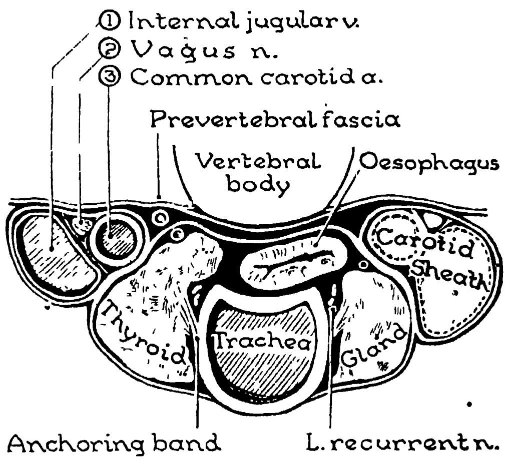


Fig. 684. The trachea and oesophagus, on cross-section.

and oesophagus and supplies them with many twigs but it moves forwards on to the side of the upper inch of the trachea. The oesophagus also has the common carotid artery and the thyroid gland for lateral relations. The cervical pleura, as far as the neck of the 1st rib, the thoracic duct on the left side as far as the 7th C. vertebra, and branches of the inferior thyroid artery. The left border of the oesophagus projects beyond the trachea (*fig. 684*) and it is from this more accessible or left side that the surgeon prefers to approach the oesophagus.

THE LATERAL ASPECT OF THE SKULL (NORMA LATERALIS)

Orientation. The anthropological position of a skull is one in which the lower margins of the orbital cavities and the upper margins of the external auditory meatuses lie on the same horizontal plane—the Frankfort plane. This is roughly attained by placing a 2-inch block under the margin of the foramen magnum while the chin rests on the table. The angles of the jaw are thereby raised slightly from the table; the foramen magnum faces downwards with a slightly forward inclination; the bregma lies about

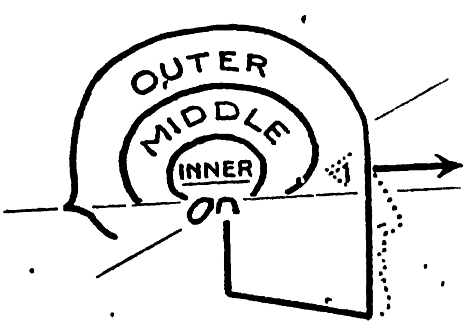


FIG. 685. Plan of the side of the cranium and face. The face is angular. The cranium is oval and is divided into three zones placed above twin depressions.

an inch in front of the vertex. This approximates the anatomical position in the living subject in whom the optical axes look forwards.

The skull has two parts, the *cranium* or brain-case and the *face* or part mainly concerned in mastication and respiration, and it affords protection to the organs of special sense. The cranium is rounded; the face is angular (*fig. 685*). The cranium is twice the size of the face; but at birth, before the eruption of teeth and development of air sinuses, the cranium is 8 times as large as the face.

A straight line carried from the nasion to the tip of the mastoid process divides the skull into cranial and facial parts with fair but not perfect accuracy, because it passes below the zygomatico-frontal suture and through the neck of the jaw and so leaves the frontal process of the zygomatic bone and the condyle of the jaw, both of which belong to the face, on the cranial side of the "base" line.

The Cranium on Lateral View (*fig. 686*) presents 3 approximately "concentric" ovoid contour lines (1) the outline of the cranium, (2) the outline of the temporal fossa, (3) the outline of the squama of the temporal bone.

THE OUTERMOST OVOID CONTOUR LINE is the outline of the cranium. It occupies the median plane and its features are: nasion, glabella, bregma, vertex, lambda, posterior pole of the skull, inion, and foramen magnum. The *glabella* lies above the nasion and between the superciliary arches, and is the most anterior point on the contour. The *inion*, directed downwards due to the pull of the ligamentum nuchae, is easily palpated just below the Frankfort plane. It was formerly the custom to record the length of skulls in terms of the nasion—inion diameter; at present it is usual to measure from the glabella to the most distant point in the median plane, called the *posterior pole*. It lies between the inion and the lambda. The *lambda* is 2½ inches above the inion. Above the level of the inion lies the cerebrum, and the outline of the cranium is here full; below lies the cerebellum, and the outline shelves to the foramen magnum, whose center is deep to the mastoid process. From nasion to foramen magnum the frontal, parietal, and occipital bones contribute nearly equally to the outline. From the inion the *superior nuchal line* curves laterally to the rough lower half and tip of the *mastoid process*, which is the drawn-out end of the line. To these the Trapezius and Sterno-mas-

toid are attached, and deep to the latter are the Splenius and Longissimus Capitis. The upper, smooth, triangular part of the mastoid lies behind the external auditory meatus and closes the tympanic (mastoid) antrum laterally. Actually, this triangular area of bone is a downward extension from the squama temporalis, as can be seen at birth before the squamo-mastoid suture closes (*fig. 780 A*). The remains of this suture are often apparent in the adult.

THE INNERMOST OVOID CONTOUR LINE is the border of the squama temporalis. Side by side below its middle are twin cavities—the *external auditory meatus* and the *mandibular fossa.* From the squama projects the zygomatic process. In the following respects the *zygomatic process* recalls the coracoid process of the scapula: in having a broad flat origin, a change in direction, a terminal fingerlike part, a tubercle for a ligament (temporo-mandibular or conoid) where the direction changes, and in partaking in a joint cavity (temporo-mandibular or shoulder). The *zygoma* or zygomatic process of the temporal bone articulates with the temporal process of the zygomatic bone, and both take part in the zygomatic arch.

The *lower border of the zygomatic arch* begins at the 2nd molar tooth and ascends as a buttress to the zygomatic process of the maxilla, separating the facial aspect of the skull from the infratemporal fossa. It then curves backwards along the lower border of the zygomatic bone and zygoma to the *tubercle* for the temporo-mandibular ligament. Then, as the *anterior root of the zygoma,* it makes a right-angle turn medially and, ceasing to be free, ends as the *articular eminence,* which bounds the mandibular fossa in front. The anterior border of the eminence is continuous with a ragged crest, the *infratemporal crest,* on the squama temporalis and greater wing of the sphenoid that separates the temporal fossa from the infratemporal fossa.

THE INTERMEDIATE OVOID CONTOUR LINE surrounds the temporal fossa and gives attachment to the temporal fascia. It comprises the following parts: the sharp *upper border of the zygoma* which, behind the tubercle for the temporo-mandibular ligament, becomes the *posterior root of the zygoma,* which passes above the mandibular fossa and external

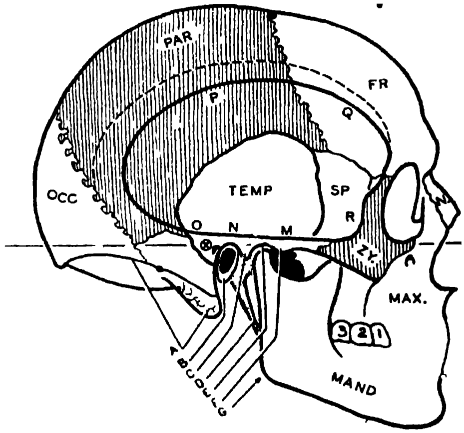


FIG. 686. The norma lateralis. (A) Supr. nuchal line and mastoid process. (B) External auditory meatus. (C) Post. glenoid tubercle. (D) Styloid process. (E) Mandibular fossa. (F) Tubercle on root of zygoma. (G) Angle of jaw (gonion). (M) Upper border of the zygoma. (N) Posterior root of zygoma. (O) Supramastoid crest. (P) and (Q) Lower temporal line. (R) Temporal border of zygomatic bone. ∞. Overlies tympanic antrum.

auditory meatus to become the *supramastoid crest,* which happens to lie between the tympanic antrum below and the middle cranial fossa above; then, as the *temporal line,* it passes on to the blunt postero-inferior angle of the parietal bone and curves across the external surface of the parietal and frontal bones to the zygomatic process of the frontal bone; thereafter it follows the angled *temporal border of the zygomatic bone,* and so completes the ovoid.

The temporal line is double except in front; the outer line is for the temporal fascia; the inner line limits the origin of the temporal muscle.

The *temporal fossa* is deepest at its antero-inferior angle, above the coronoid process of the jaw. Parts of the zygomatic bone and great wing of the sphenoid form its anterior wall and separate it from the orbital cavity. The temporal line separates it from the region of the scalp. The zygomatic arch and infratemporal crest separate it from the infratemporal fossa. Four bones take part in its medial wall and meet at a + or H-shaped suture called the **pterion**. The four bones are the temporal squama, greater wing of sphenoid, parietal, and frontal. The pterion is a landmark full of importance, overlying (a) the *anterior branch* of the middle meningeal artery which occupies a groove or canal at the antero-inferior angle of the parietal bone; (b) the *tip of the lesser wing* of the sphenoid, and therefore (c) the stem of the *lateral cerebral fissure* of Silvius, and therefore (d) the *middle cerebral artery*, etc. The pterion is located in the angle formed by placing the thumb behind the frontal process of the zygomatic bone and two fingers above the zygomatic arch (Stiles) (*fig. 649*).

THE STYLOID REGION. The *styloid process* of the temporal bone projects below the external auditory meatus and in front of the root of the mastoid process. Its tip disappears deep to the ramus of the jaw well above the angle. The *post-glenoid tubercle*, large in some animals, descends from the posterior root of the zygoma behind the condyle of the jaw. The *suprameatal spine* lies behind the auditory meatus just below the supramastoid crest.

On account of their central positions and simple features the *parietal bone* has been selected from among the cranial bones and the *zygomatic bone* from among the facial bones as "key bones" worthy of individual treatment; and the *lower jaw*, which is the only movable bone in the skull, is also described in some detail.

The Parietal Bone, paired, will be examined in some detail on account of its central position and simplicity. Its features are its angles and borders. It is classified as a flat bone, with two surfaces, four borders and four angles, and is moulded on the brain. (*Figs. 686, 687.*)

Borders. Three borders are straight and serrated and each articulates with one bone: the anterior with the frontal bone at the parieto-frontal or *coronal suture*, the superior with the opposite parietal bone at the interparietal or *sagittal suture*, and the posterior with the occipital bone at the parieto-occipital or *lambdoid suture*. The inferior border is concave and has the appearance of having been scraped away externally to articulate with the squama of the temporal bone which overlaps it. This, the *parieto-squamous suture*, is easily sprung.

Angles. Each of the 4 angles has a different shape, is in relation on its medial surface with an important vessel, and is situated at a named location. The antero-inferior angle is acute; it has on its medial surface either a shallow groove, a deep groove with overhanging edges, or a canal for the anterior branch of the middle meningeal artery; and it rests on the greater wing of the sphenoid at the lower end of the coronal suture, at the region called the *pterion*. The antero-superior angle is a right angle, is grooved medially by the superior longitudinal sinus, and is situated at the junction of the coronal and sagittal sutures at a point called the *bregma*. The postero-superior angle is rounded, is also grooved by the superior longitudinal sinus, and is

situated where the lambdoid and sagittal sutures meet at a point called the *lambda.* The postero-inferior angle is blunt, is grooved medially by the transverse sinus, and is situated on the mastoid bone. Its most posterior point lies at the lower end of the lambdoid suture at a point called the *asterion.*

Surfaces. The lateral surface is convex. At the point of greatest fulness, the *parietal eminence or protuberance,* ossification started and spread concentrically and therefore reached the 4 angles late.

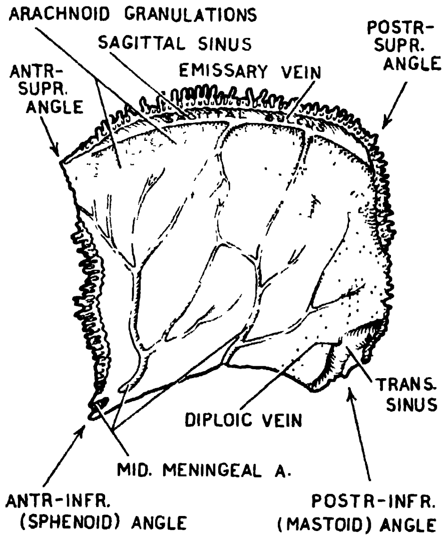


FIG. 687. The medial surface of the parietal bone.

They are unossified at birth, and owing to the pulsations transmitted by the underlying brain, are called fonticuli or fontanelles (*p. 589*). Two lines, the *upper* and *lower temporal lines,* placed ½ an inch apart, curve across the lateral surface from the postero-inferior angle to the anterior border, and divide the surface into an upper ⅔ covered by the scalp and a lower ⅓ which forms part of the temporal fossa. The temporal fascia is attached to the upper line; the temporal muscle reaches to the lower line.

The medial surface is concave. Grooves for branches of the middle meningeal vessels ascend on it, one being commonly about a finger's breadth behind the anterior border. A groove, being one-half of the *sagittal sulcus,* extends beside the superior border. It lodges the sagittal sinus. By its side are depressions for arachnoid granulations. An inch or two anterior to the postero-superior angle a foramen, the *parietal foramen,* transmits an emissary vein from the superior sagittal sinus to the surface veins.

The Facial Portion of the Skull, on lateral view, is angular in outline, the apex being the point of the chin. From the nasion to the head (condyle) of the jaw the outline is formed by: the nasal bones; the sharp margin of the anterior nasal aperture formed by the nasal and maxillary bones and ending below in the anterior nasal spine of the maxillae; the upper alveolar process, the upper and lower central incisor teeth; the lower alveolar process; mental protuberance; point of the chin, lower border (base) of the mandible; angle of the mandible; posterior border of the ramus, neck and head of the mandible.

A partial view of the medial wall of the orbital cavity is obtained, because the lateral margin of the orbit is half-an-inch behind the medial margin; hence, man has some lateral (or temporal) vision.

Observe that when the teeth are in occlusion each upper tooth, except the last molar, bites on parts of two lower teeth. Run the edge of your thumb nail along the crowns of your upper teeth, when closed, noting that the upper dental arcade overlaps the lower one.

The Zygomatic Bone or cheek bone (paired) is a flat bone shaped somewhat like a diamond set on end. The slightly convex lateral or *facial surface* is separated from the medial aspect by 4 angles

and 4 borders (*fig. 688*). The upper triangular half intervenes between the orbital cavity and the temporal fossa. The lower triangular half intervenes between the facial aspect of the skull and the infratemporal fossa. All four angles and the *maxillary border* (really a surface) are articular; 3 borders are free. Of these the *orbital border* is concave and gives attachment to the palpebral fascia; the *masseteric border* is tubercular for the tendinous origin of the Masseter; and reaches to the inferior orbital fissure, which divides it into 2 parts: the part medial to the fissure articulates with the maxilla; the part lateral to the fissure articulates with the greater wing of the sphenoid.

The bone is traversed by a Y- or V-shaped canal. The stem of the canal opens on to the orbital surface in front of the inferior orbital fissure. One limb opens near the center of the facial surface, the other on the temporal surface.

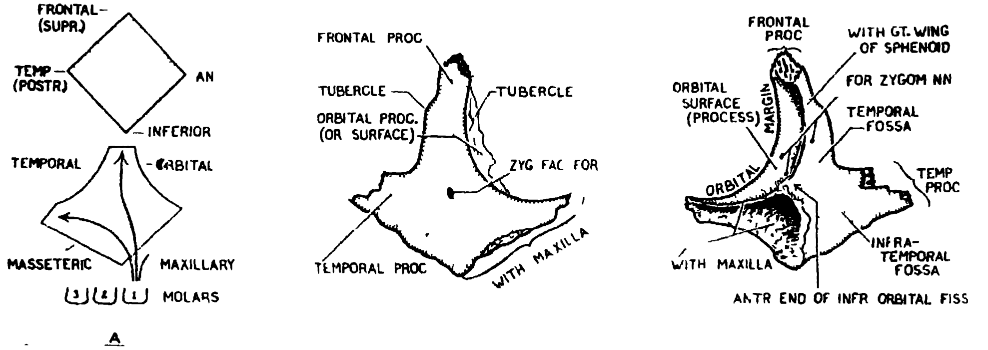


FIG. 688. The zygomatic bone. A. 4 angles, 4 borders and lines of force transmission. B The lateral surface. C. The medial aspect.

the *temporal border* is angled and sharp for the temporal fascia.

The functions of the bone are to help to anchor the maxilla, to disperse to the cranium the force of impacts delivered during mastication, and to give origin to the Masseter. Its worth is well appreciated on viewing the zygomatic process of the maxilla from below.

The zygomatic bone is but the apical part of the maxilla developed in membrane from a separate center (or centers) of ossification. Commonly the two bones unite in later life. The maxillary sinus sometimes invades the zygomatic bone.

A process of the zygomatic bone extends backwards from the orbital margin and forms part of the lateral wall and floor of the orbit. This *orbital process* These transmit the zygomatico-facial and zygomatico-temporal branches of the zygomatic nerve and vessels.

The Mandible or Lower Jaw (*figs. 689, 690*) as a whole is shaped like a horse-shoe. Each half is L-shaped consisting of two oblong parts. The horizontal parts of the two sides fuse at the *symphysis menti* in the median plane during the 2nd year to form the *body* of the jaw (in most mammals, however, the bone remains paired): the vertical parts of the two sides are the *rami*.

THE BORDERS OF THE BODY. The *lower border* of the body is thick and rounded and is continuous behind on each side with the lower border of the ramus, which is thin; together these form the lower border or *base of the jaw*. The

alveolar process or upper part of the body carries eight teeth. The roots of the teeth (except the 2nd & 3rd molars) cause rounded ridges on the thin front wall of the alveolar process, that of the canine being the most prominent. Medial to the canine ridge, and therefore in front of the roots of the incisors, is the *incisive fossa* from which the Mentalis takes origin.

THE RAMUS is an oblong, nearly vertical, flattened plate. It is surmounted by two processes: a posterior articular one, the *head* or *condyle*, and an anterior

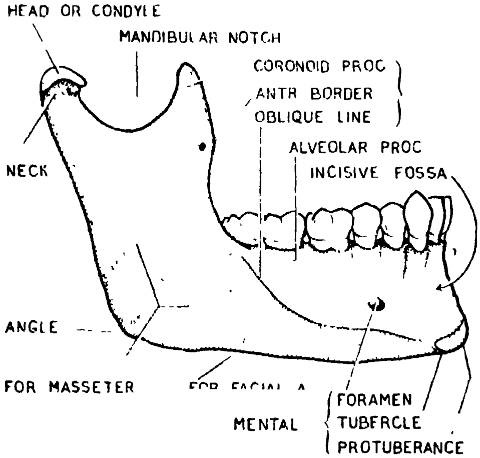


FIG. 689. The lateral aspect of the mandible.

one, the *coronoid process*; they are separated from each other by a U-shaped notch, the *mandibular notch*. The head articulates with the mandibular (articular) fossa of the temporal bone, and is like a ¾ inch segment of a lead-pencil set horizontally but not in perfect alignment with its fellow, since the medial end is tilted backwards. It is supported by a *neck*. In front of the medial part of the neck there is a *fossa* for the insertion of the tendon of the Lateral Pterygoid. The coronoid process is a traction process, caused by the pull of the Temporalis, and is therefore comparable to the mastoid process, caused by the pull of the Sternomastoid. It rises under shelter of the zygomatic arch and is triangular (or, rather, like a parrot's beak, being convex in front and concave behind).

The posterior and inferior borders of the ramus meet at the *angle* of the jaw. It is greater than a right angle, thin, rounded and either inverted or everted. Laterally it is ridged for tendinous septa of the Masseter, medially for tendinous septa of the Medial Pterygoid.

THE MANDIBULAR CANAL. Through the bone runs a canal, the *mandibular canal*. Its entrance, the *mandibular fora-*

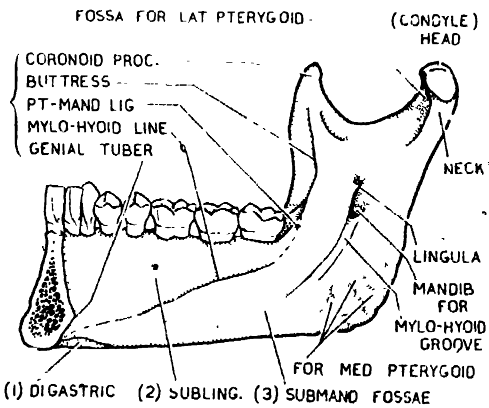


FIG. 690. The medial aspect of the mandible.

men, lies at the centre of the medial surface of the ramus, above the level of the crowns of the molar teeth. Guarding the foramen in front is a small, upwardly projecting tongue, the *lingula*, which gives attachment to the sphenomandibular ligament. A narrow groove, the *mylohyoid groove*, which lodges the mylohyoid nerve and artery, begins behind the lingula and runs for an inch obliquely downwards and forwards on the ramus. The canal, conveying vessels and nerves to the teeth, continues to the symphysis menti, but it communicates with the outer surface of the body

at the *mental foramen*, situated $1\frac{1}{4}$ inches from the symphysis, in line between the bicuspid teeth, and midway between the lower border of the jaw and the alveolar border. The margins of the foramen are sharp, except above and laterally, because the emerging mental nerve and artery are mainly distributed in these directions.

THE SURFACES OF THE BODY. *External.* In front of the lower end of the symphysis menti there is a broad triangular elevation, the *mental protuberance.* From the infero-lateral angle of this protuberance (mental tubercle) an indefinite line, the (external) *oblique line,* crosses the body diagonally upwards and backwards below the mental foramen to become continuous with the sharp anterior border of the ramus and coronoid process. To this line are attached the Depressor Labii Inferioris and Depressor Anguli Oris. *Internal*--Behind the middle of the symphysis there are two pairs of small tubercles, the *genial tubercles* (mental spine) for the origin of the Genio-hyoid and Genio-glossus. From below the genial tubercles another oblique line, the *mylohyoid line,* crosses the body diagonally upwards and backwards to become (nearly) continuous with a strengthening *buttress* on the medial aspect of the coronoid process. To this line the Mylohyoid is attached. Between the mylohyoid line and the buttress the pterygomandibular ligament is attached, and also the two muscles attached to this ligament, namely the Superior Constrictor behind and the Buccinator in front, the Buccinator extending forward abreast of the 1st molar tooth. Three fossae are related to the mylohyoid line: (1) the *digastric fossa,* for the attachment of the anterior belly of the Digastric, resembles a finger-tip impression made on modelling clay, and is situated below the line, at the side of the symphysis; (2) the *sublingual fossa,* for the sublingual salivary gland is above the line, and (3) the *submandibular fossa* for the submandibular salivary gland is below it.

THE PAROTID REGION

The parotid region (Gk. para = near; ous (otos) = the ear) is a mould lined with fascia and filled, not with fat, but with parotid salivary gland. The gland fills the irregularities of the mould and overflows its brim in front and below, and through the gland pass certain vessels and nerves.

If you make a careful study of the mould you need not devote time to the cast which is but the counterpart of the mould; moreover, the form and relations of the parotid mould are more easily investigated than those of the parotid gland.

The parotid gland is invested in deep cervical fascia which splits to enclose it. The superficial layer reaches the zygoma; the deep layer lines the mould and reaches the lower border of the tympanic plate. The gland itself falls short of the zygoma.

THE COMPOSITION OF THE PAROTID MOULD (*fig. 673*). *Behind:* the anterior border of the Sterno-mastoid and mastoid process. *In front:* the posterior border of the ramus of the jaw and of the Medial Pterygoid and Masseter, which are inserted into the ramus. Here the gland overflows on to the Masseter as the facial process. *Above:* the anterior and posterior boundaries meet below the post-glenoid tubercle in the cleft between the capsule of the (temporo-)mandibular joint in front and the cartilaginous and bony external auditory meatus behind. *Below:* the Stylo-hyoid and the posterior belly of the Digastric. These the gland overflows, thereby encroaching on the carotid triangle.

The deep part or *bottom of the mould* is formed by: (1) The styloid process and the three muscles that arise from it. They intervene between the parotid gland and the internal jugular vein, internal carotid artery, and the last four cranial nerves. (2) The fascial lining adheres—according to rule—to the styloid process and to the posterior border of the ramus of the mandible. Between these two bony parts it is ballooned forwards like a sail before the wind, deep to the Medial Pterygoid. The lower part of this sheet is especially strong. It separates the parotid gland from the submandibular gland, and is called the *stylo-mandibular ligament.*

Several rounded ridges in the mould cause rounded grooves in the cast. They are: (a) the mastoid process and Sterno-mastoid, (b) the posterior border of the ramus, (c) the Digastric, and (d) the styloid process.

Several tongue-like projections from the cast (parotid lobules) fill several crevices in the mould. Of these, (a) one passes forwards between the upper part of the ramus and the Medial Pterygoid; (b) another passes upwards between the tympanic plate and the capsule of the temporo-mandibular joint; (c) another passes medially in front of the internal carotid artery to the Superior Constrictor; but (d) the largest projection is the facial process. It covers the hinder part of the Masseter (and the temporo-mandibular l'g. and neck of the jaw) and is prolonged above the parotid duct as the *accessory parotid gland.*

The **Parotid Duct** (Stensen's duct) crosses the Masseter a finger's breadth below the zygomatic arch, turns at right angles round the anterior border of the Masseter, and then pierces the buccal fat, Buccinator, and mucous membrane of the cheek to open in the vestibule of the mouth, where its orifice, constricted as orifices usually are, can be seen at the level of the crown of the 2nd upper molar tooth.

THE FOLLOWING RADIATE FROM THE PERIPHERAL MARGIN of the gland: (1) The superficial temporal artery and vein, accompanied by the auriculo-temporal nerve, cross the posterior root of the zygoma; the temporal branches of the facial nerve cross the zygomatic arch.

(2) Other branches of the facial nerve (zygomatic, buccal, mandibular) and the transverse facial branch of the superficial temporal artery, which runs above the parotid duct, cross the Masseter.

(3) The cervical branch of the facial nerve enters the neck just below the angle of the jaw.

(4) The posterior auricular artery and the posterior auricular branch of the facial nerve which supplies three vestigial muscles (Occipitalis, Auricularis Posterior, and Auricularis Superior) cross the mastoid.

THE STRUCTURES WITHIN THE MOULD AND PASSING THROUGH THE GLAND (*fig. 691*) are:

1. First, foremost, and superficial even to the veins is the *facial nerve.*
2. The posterior facial vein.
3. The external carotid artery and its terminal branches.
4. Auriculo-temporal nerve.
5. Great auricular nerve.
6. Lymph glands.

The **Facial Nerve** (N. VII) can be found with ease and rapidity provided the subjoined fairly obvious facts are borne in mind: (a) the facial nerve makes its entrance into this region through the stylo-mastoid foramen. (b) The name of the foramen betrays its location—between styloid process and mastoid process. (c) Only one branch of the facial nerve passes backwards, and it, the

posterior auricular nerve, is of no importance. (d) The margin of the stylo-mastoid foramen is nowhere rounded because the stem of the nerve does not at once turn forwards but runs a short downward course before plunging into the posterior surface of the parotid, which it does 1″ below the condyle. (e) The facial nerve crosses superficial to (all) the vessels it meets.

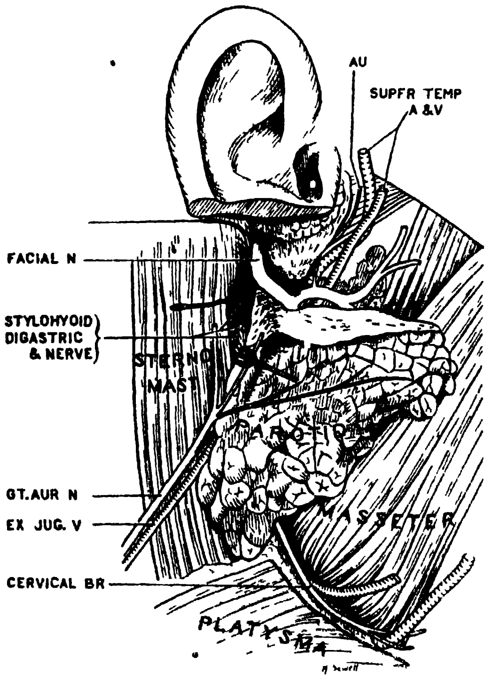


FIG. 691. Exposure of the stem of the facial nerve. (The upper part of the parotid gland has been cut away.)

Therefore, cut downwards on to the mastoid bone, avoiding the posterior auricular artery but disregarding the nerve of the same name. With the handle of the knife ease the gland well forwards from the mastoid process and stylo-mastoid foramen. The stem of the nerve lies between the gland and its sheath, so, it also will be eased forwards. Pick it up before it enters the gland substance and divides into upper and lower divisions; then trace the nerve through the gland making deep cuts radially in the course of the main branches.

The posterior auricular branch and the branch to the posterior belly of the Digastric and Stylohyoid arise before the nerve enters the gland.

At birth the child has no mastoid process and the stylo-mastoid foramen is subcutaneous; consequently, the facial nerve may be severed accidentally by a deep skin incision made behind the ear. As the process develops the foramen and stem of the nerve become covered.

The External Carotid Artery appears from under cover of the Digastric and Stylo-hyoid, ascends through the deep part of the gland and under shelter of the posterior border of the ramus of the jaw to the neck where it divides into its two terminal branches: (1) the *internal maxillary artery* which, hugging the neck of the jaw, passes forwards into the infra-temporal region; and (2) the *superficial temporal artery* which, after giving off transverse facial and parotid branches, crosses the root of the zygoma where its pulsations can be felt. The posterior auricular branch of the external carotid artery follows the upper border of the Digastric, sends an important branch into the stylo-mastoid foramen, and then crosses the mastoid (*fig. 670*).

The Posterior Facial Vein, formed by the junction of the superficial temporal and internal maxillary veins, traverses the gland superficial to the external carotid artery, divides into two branches which pass superficial to the Digastric and help to form the common facial and the external jugular vein (*fig. 628*).

The Auriculo-temporal Nerve runs laterally behind the capsule of the joint at the level of the neck of the jaw, and then ascends to cross the posterior root of the zygoma. It may pierce the gland. Here

it sends twigs to the joint, and to the external auditory meatus and outer surface of the ear drum by fibers that pass between the bony and cartilaginous portions of the meatus. It communicates with the facial nerve and conveys secretory fibers to the parotid gland. Beyond this it is distributed to the front of the auricle and the scalp

The Great Auricular Nerve sends some anterior branches through the parotid gland to the cheek, and some communicate with the facial nerve.

SUPPLY. The *arteries* traversing the gland supply it. *Lymph glands*, superficial and deep to the parotid fascia, drain cutaneous areas mostly above the zygomatic arch (scalp, eyelids, and auricle) Their efferents follow the external jugular vein; others enter the upper deep cervical glands. Glands *within the parotid* drain deeper parts (external auditory meatus, tympanum, soft palate, deep parts of the cheek) and drain into deep cervical glands. *Nerves:* Sympathetic fibers reach the gland via the external carotid plexus; they are vasoconstrictor. The glosso-pharyngeal nerve, via lesser superficial petrosal nerve, otic ganglion, and auriculo-temporal nerve, provides the parotid with secretory fibers. (*Fig. 744.*)

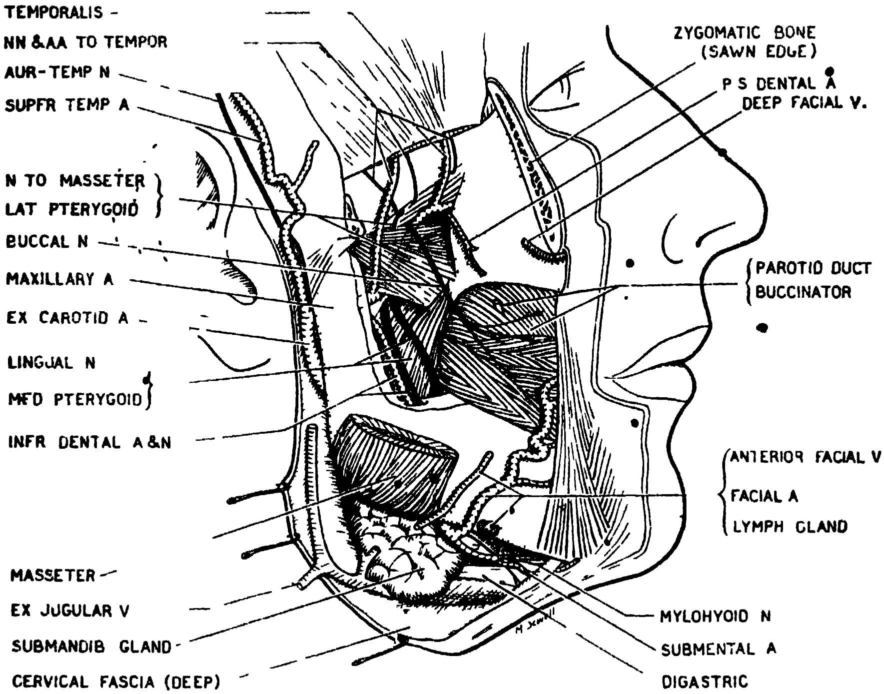


FIG. 692. The temporal, infratemporal and submandibular regions

The Temporal and Masseteric Muscles.

THE FASCIAE. *The Temporal Fascia* is strong and is attached to the limits of the temporal fossa, described on page 677 as an intermediate ovoid area. It splits below into 2 layers which enclose some fat; the superficial layer is attached to the upper border of the zygomatic arch rendering it sharp; the deep layer descends deep to the Masseter. The middle temporal branch of the superficial

temporal artery pierces the fascia and ascends in a groove on the squamous temporal; the zygomatico-temporal nerve also pierces it.

The Masseteric Fascia is not strong; it is attached to the zygomatic arch and to the margins of the ramus.

THE TEMPORALIS is fan-shaped. It arises by fleshy fibers from the whole temporal fossa between the lower temporal line and the infratemporal crest, ——except in front where a pad of fat separates it from lateral wall of the bony orbit—and from the temporal fascia; cf., the origin of the Gluteus Medius in figure 400. It is only in primates that the temporal and orbital cavities are separated by bone; e.g., in the dog they are separated by a membrane containing involuntary muscle fibers of Muller. The insertion or handle of this fan-shaped muscle is necessarily tendinous; it is attached to the circumference of the coronoid process, which is an "epiphysis" without a separate center of ossification The tendon necessarily begins on the superficial surface because the fleshy fibers are all of approximately the same length and the lowest pass to the medial surface of the coronoid process (*fig 625*).

THE MASSETER is rhomboidal. It arises by tendinous fibers from the anterior ⅔ of the lower border of the zygomatic arch, which accordingly is tubercular, and by fleshy fibers from the medial surface of the arch and posterior ⅓ of the lower border, which accordingly are smooth. It covers the greater part of the lateral surface of the ramus and is inserted into it, but owing to its obliquity it leaves bare the capsule of the joint and the neck of the jaw. It has a common developmental origin with the Temporalis and is partly united with it.

In order to find the vessels and nerve to the Masseter, insinuate a probe between the posterior border of the Masseter and the neck of the jaw and sweep it upwards till the vessels and nerve arrest it. Leaving the probe in this position, detach the posterior third of the muscle from the zygomatic arch and note that the vessels reach the Masseter by crossing the mandibular notch below the Lateral Pterygoid; the nerve by crossing above it. This relationship is in keeping with the generalization stated below.

THE INFRATEMPORAL REGION

The infratemporal region lies below the temporal fossa and deep to the ramus of the mandible. Without some preliminary knowledge of the bony boundaries of the region the contents cannot usefully be discussed The facts to appreciate are these:

BONY PARTS (*figs. 693, 694*). The ramus of the mandible forms the *lateral wall* of the infratemporal fossa. Its lateral surface is described on page 681.

Its medial surface has near its center the *mandibular foramen.* The anterior margin of the foramen projects upwards and medially as a small tongue, the *lingula*, and from the foramen a groove, the *mylohyoid groove*, runs downwards and forwards for an inch. The area between the groove and the angle is ridged for the fibrous attachment of the Medial Pterygoid. The *head* and *neck* when viewed from in front or behind are seen to project medial to the ramus. In front of the neck there is a depression for the insertion of the Lateral Pterygoid.

The *coronoid process*, which limits the mandibular notch anteriorly, is recurved and strengthened medially by a bar of bone. It is to the temporal muscle what the mastoid process is to the sternomastoid muscle—the site of its tendinous insertion—and each process points in the direction of pull.

The anterior wall, medial wall, and roof of the fossa are seen when the mandible is removed. The *anterior wall* is formed by the inflated body of the maxilla and is of eggshell thickness. It is separated from the facial surface of the maxilla by the *buttress* that descends from the zygomatic arch to the 2nd molar tooth. It is limited below by the 2nd and 3rd molar teeth and the part of the alveolus behind them, called the *tuberosity of the maxilla;* above, by the *inferior orbital fissure;* and behind by the *pterygo-palatine fossa.*

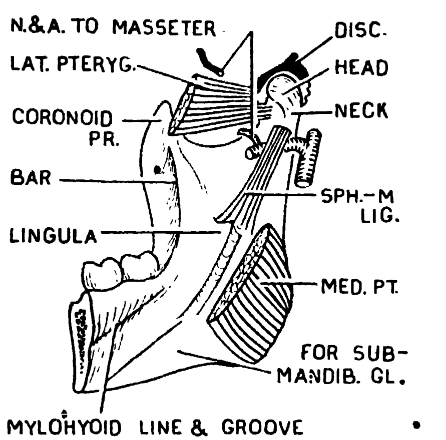


FIG. 693 The lateral wall of the infratemporal fossa: i.e , the ramus of the jaw.

The Medial Wall is formed by the *lateral or muscular plate* of the pterygoid process and is half-an-inch wide. The *pterygoid process* is a flying buttress for the support of the anterior wall; accordingly, it slopes downwards and forwards so as to abut against the posterior border of the maxilla above the tuberosity. It assists the zygomatic arch in preventing the face from being driven backwards under the cranium. The cleft above the point of abutment is the *pterygo-palatine* (pterygo-maxillary) *fossa.* It is the hiding place of the spheno-palatine ganglion and of the 3rd part of the maxillary artery.

The Roof is flat and is formed by the under surface of the *greater wing of the sphenoid.* In front of the articular eminence the squamous temporal takes part in the roof. A ragged edge, the *infratemporal crest,* separates the roof from the medial wall of the temporal fossa. The *foramen ovale* perforates the roof at the posterior border of the lateral pterygoid plate—and, the plate is the guide to the foramen. The *foramen spinosum* perforates just postero-lateral to the foramen ovale at the root of the *spine of the*

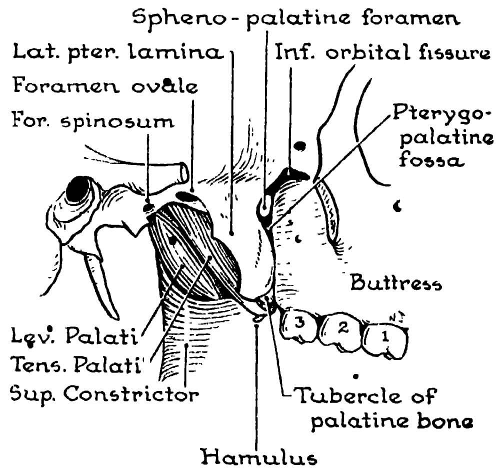


FIG. 694. The medial and anterior walls and the roof of the infratemporal fossa.

sphenoid, which forms the medial limit of the mandibular fossa. The inferior orbital fissure opens into the fossa at right angles to the pterygo-palatine fossa.

Restore the mandible to the skull and observe that a pencil passed through both mandibular notches and across the base of the skull encounters no obstruction (*fig. 695*). It is found to lie at the roots of the lateral pterygoid plates below the oval foramina.

DISSECTION. Complete the detachment of the Masseter from its origin, throw it downwards and thereby leave bare the lateral surface of the ramus of the jaw. The ramus forms

the lateral wall of this fossa, so, it must in part be removed. Before this is done, observe that the mandibular foramen, into which the inferior dental vessels and nerve pass, lies at the "center" of the medial surface of the ramus, and note that this point ("the center") lies above the plane of the crowns of the molar teeth. With a pencil, mark this point on the outer surface of the ramus. Pass one blade of a pair of dissecting forceps across the deep surface of the ramus from posterior to anterior border, and press it downwards so that it shall catch on the lingula, which gives attachment to the vestigial spheno-mandibular ligament and

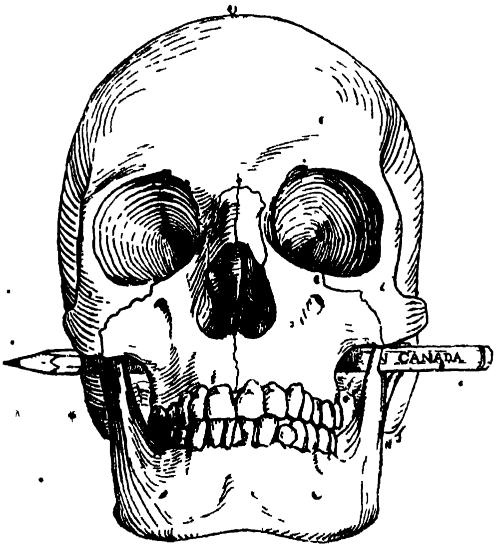


FIG. 695. A pencil can be passed through both mandibular notches

guards the mandibular foramen. Then, using the blade to protect the deep structures, either (a) saw through the ramus as low as possible and through the neck and coronoid process high up; or better (b) leaving the condyle and posterior border of the ramus intact, cut away the coronoid process and front of the ramus.

CONTENTS:

1. The Pterygoideus Medialis.
2. The Pterygoideus Lateralis.
3. The mandibular nerve.
4. The (internal) maxillary artery.

The Medial Pterygoid is the most medial structure in the region (*fig.* 696). It arises from the medial surface of the lateral pterygoid lamina (a few fibers, it is true, creep round below the lamina on to the maxillary tuberosity and on to the tubercle of the palatine bone). It crosses from the medial to the lateral wall of the infratemporal fossa in a downward and backward direction to be attached to the whole of the medial surface of the ramus below and behind the mandibular foramen.

Both the Medial Pterygoid and the Masseter are rhomboidal; both take downward and backward courses; and both are inserted into roughly corresponding areas on the two surfaces of the ramus. The difference to note is the added lateral direction of the Medial Pterygoid, because this affects its action.

The Lateral Pterygoid has a continuous origin from almost the entire roof and medial wall of the infratemporal fossa. If you wish you may describe upper and lower heads. The fibers converge as they pass backwards and laterally to be inserted into the pit in front of the neck of the jaw and into the articular disc. The muscle is triangular; it has therefore a tendinous insertion; it also passes from medial to lateral wall; its lower border is nearly horizontal; it conceals the origin of the Medial Pterygoid. The nerve of the region is deep to it; the artery is superficial.

Generalization. The *maxillary artery* enters the region in contact with the medial side of the neck of the jaw—i.e., in contact with the hindmost part of the lateral wall of the infratemporal fossa. The *mandibular nerve* (V_3) enters the region through the foramen ovale—i.e., through the most medial part of the roof of the infratemporal fossa. Now, the foramen ovale lies above a pencil passed through both mandibular notches. Obviously, therefore, it lies above and in

front of a line joining the necks of the jaw. Hence:

(1) The nerve makes its entrance above, in front of, and medial to the artery.

(2) The artery makes its entrance below, behind, and lateral to the nerve.

(3) These relative positions are maintained by the stems and branches of nerve and artery where they accompany each other and where they have occasion to cross.

The Mandibular Nerve (V^3) is a mixed nerve, for added to fibers from the trigeminal ganglion is the entire motor root of the trigeminal nerve. It enters through the foramen ovale, which is situated between the lateral pterygoid lamina and the foramen spinosum and therefore deep to the Lateral Pterygoid. It breaks up almost at once into branches each of which begins its career deep to the horizontally running Lateral Pterygoid. Because of the obliquity of the Medial Pterygoid only the descending branches of the nerve actually cross it; but the nerve and all its branches are at first superficial to the Tensor Palati, which arises medial to the foramen ovale and fills the gap between it and the oblique upper border of the Medial Pterygoid.

BRANCHES, The mandibular nerve is developmentally the nerve of the mandibular arch. It supplies the muscles of mastication and is sensory to the mandibular arch (*fig. 696*).

(1) Certain branches remain deep to the Lateral Pterygoid, namely, motor branches which pass (a) directly to the *two Pterygoids* and (b) indirectly via the otic ganglion to the *two Tensors* (Palati and Tympani), and (c) a *sensory branch*, which sends twigs through the foramen spinosum to the dura mater and through the bone to the mastoid air cells.

(2) Other branches appear at the borders of the Lateral Pterygoid or perforate it. Thus: running between its upper border and the roof of the fossa are two branches to the *Temporalis* and one to the *Masseter*. The latter crosses the mandibular notch behind the tendon of the Temporalis and sends a twig to the joint before entering the muscle.

TABLE 20

The Branches of the Mandibular Nerve

MUSCULAR BRANCHES	SENSORY BRANCHES	OTHER BRANCHES
Temporalis and Masseter	Auriculo-temporal	Taste
Medial and Lateral Pterygoids	Inferior dental	Secretory
Tensores Palati and Tympani	Lingual	Articular
Mylo-hyoid and Digastric (anterior)	Buccal	

The Buccal Branch pierces the Lateral Pterygoid (and usually fibers of the Temporalis as well), passes the anterior border of the ramus, and sends many fibers through the Buccinator to the mucous membrane of the cheek and gums (*fig. 740*).

[The *facial nerve* also has a buccal branch. Which, then, is motor to the Buccinator,——the buccal branch of the mandibular nerve or the buccal branch of the facial nerve? The mandibular nerve is a mixed nerve; facial nerve is motor only. Hence, it is the buccal branch of the facial that supplies the Buccinator. The Buccinator, therefore, belongs to the muscles of expression. As such it is employed to pout the lips, whistle, blow a bugle. It is also employed as an accessory muscle of masti-

cation. Thus, during the act of chewing, the Buccinator on the lateral side and the tongue on the medial side keep food supplied to the grinding surfaces of the teeth. When the facial nerve is paralyzed this power is lost and food accumulates between the cheeks and the teeth.]

The inferior dental (alveolar) and *lingual nerves* appear at the lower border of the Lateral Pterygoid and continue be-

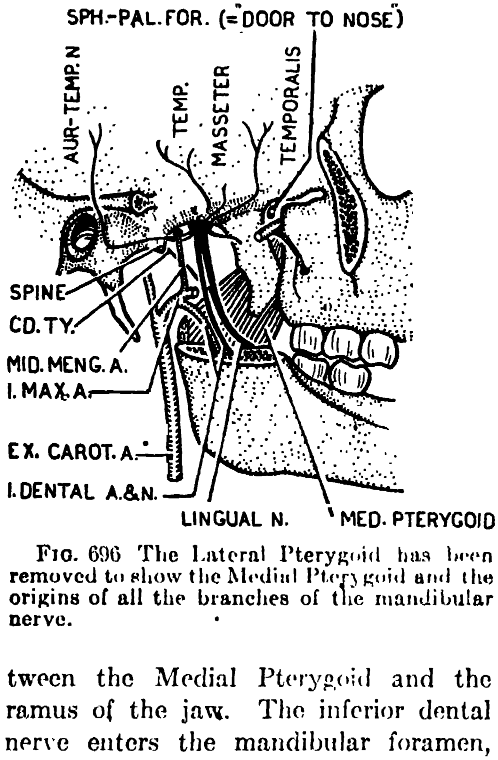


FIG. 696 The Lateral Pterygoid has been removed to show the Medial Pterygoid and the origins of all the branches of the mandibular nerve.

tween the Medial Pterygoid and the ramus of the jaw. The inferior dental nerve enters the mandibular foramen, traverses the mandibular canal, and appears on the face as the mental nerve. While in the canal it sends twigs to the teeth, including the incisors, and to the gums; and just before entering the canal it gives off the nerve to the *Mylo-hyoid* and anterior belly of the *Digastric*. The latter runs in the mylo-hyoid groove to the digastric triangle. The *lingual nerve* supplies the anterior two-thirds of the tongue, the floor of the mouth, and the gums (*fig. 741 and p. 740*); so, naturally, it lies in front of the inferior dental nerve. It enters the mouth applied to the jaw and runs forwards submucously just below the third molar tooth. The *chorda tympani nerve* leaves the tympanum through the petro-tympanic fissure, grooves the medial side of the spine of the sphenoid, and joins the lingual nerve from behind, near the lower border of the Lateral Pterygoid. It has both afferent and efferent fibers: the afferent fibers are taste fibers and are distributed with the lingual nerve to the anterior ⅔ of the tongue; the efferent fibers are secretory to the submandibular and sublingual salivary glands, and are relayed in the submandibular ganglion (*figs. 678, 735, 744*).

The Auriculo-temporal Nerve also clings to the roof. In its course backwards, deep to the Lateral Pterygoid and to the condyle, it splits to encircle the middle meningeal artery and passes lateral to the spine of the sphenoid. It then winds laterally behind the capsule of the joint, crosses the posterior root of the zygoma, and accompanies the superficial temporal artery. It is distributed to the temporal region and anterior part of the auricle; to the skin of the meatus and outer surface of the ear drum (via twigs that pass between the bony and cartilaginous meatus), and to the jaw joint. It communicates with the stem of the facial nerve, and it conveys to the parotid gland secretory fibers derived from the otic ganglion.

One could imagine a fracture of the spine of the sphenoid interfering with the secretion of the parotid, submandibular, and sublingual glands and with taste in the anterior ⅔ of the tongue, because the spine is in contact with the auriculo-temporal nerve laterally and with the chorda tympani medially.

The (Internal) Maxillary Artery (*fig. 697*) is the larger of the two terminal branches of the external carotid. It begins at the neck of the jaw, runs forwards in contact with the medial side of the neck and along and lower border of the Lateral Pterygoid, and ascends sinuously across the lateral (sometimes medial) surface of the Lateral Pterygoid and then disappears into the pterygo-palatine fossa, where it breaks up into its end branches.

It is divided by the Lateral Pterygoid into three parts——1st, before crossing; 2nd, crossing; 3rd, after crossing and therefore in the pterygo-palatine fossa.

Branches. All branches of the 1st and 3rd parts pass through foramina; the branches of the 2nd part are muscular.

From the 1st Part (a) *The deep auricular a.* follows the branch of the auriculo-temporal nerve between the cartilage and bone of the auditory meatus to supply the skin of the meatus and (outer surface of) the ear drum. (b) *The anterior tympanic a.* ascends behind the capsule of the joint and through the petro-tympanic fissure into the tympanum. (c) *The middle meningeal a.* ascends medial to the Lateral Pterygoid and then between it and the Tensor Palati, pierces the auriculo-temporal nerve, and passes through the foramen spinosum. (d) *The accessory meningeal a.* ascends between the same muscles and passes through the foramen ovale to supply the trigeminal (semilunar) ganglion and adjacent dura mater. (e) *The inferior dental a.* accompanies the nerve of the same name and has corresponding branches, including a short mylo-hyoid branch, and a branch accompanies the lingual nerve.

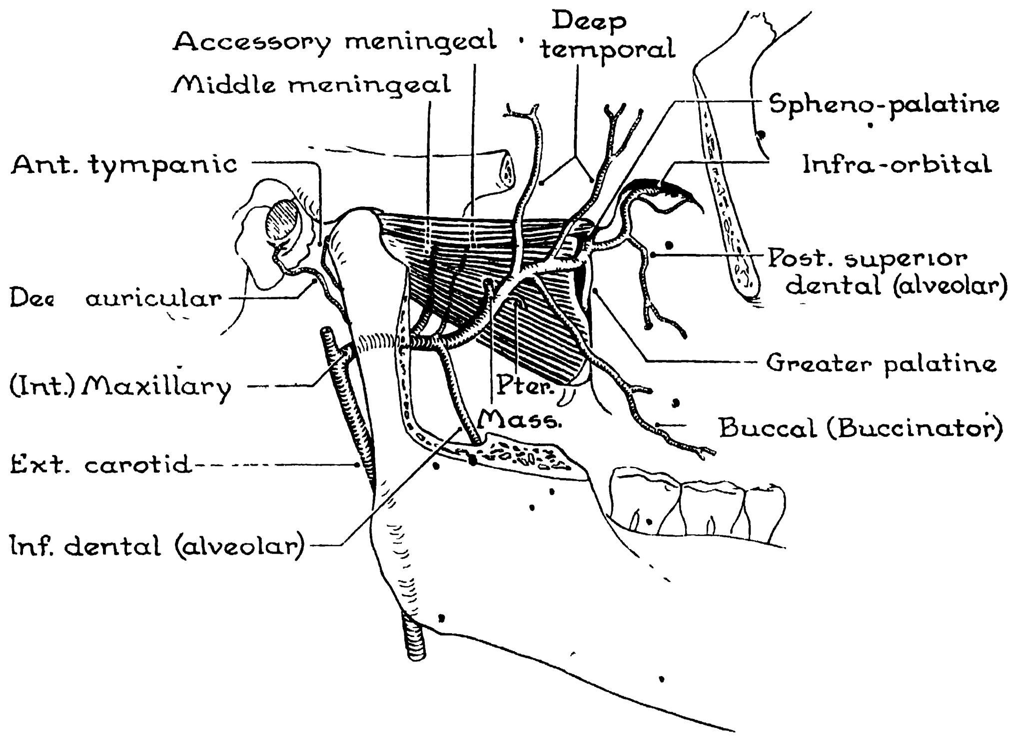


Fig. 697. The (internal) maxillary artery.

From the 2nd Part. Muscular

branches to the Lateral and Medial Pterygoids, branches that join the nerves to the Temporalis and Masseter (after they have crossed the Lateral Pterygoid), and a branch that follows the buccal nerve.

From the 3rd Part. The posterior superior dental, infra-orbital, greater (descending) palatine, artery of the pterygoid canal, pharyngeal, and the spheno-palatine arteries. These accompany branches of the maxillary nerve (V^2) through bony canals or foramina and will be studied later.

The Internal Maxillary Vein. Veins corresponding to branches of the artery form a plexus, the *pterygoid plexus,* which begins in the pterygo-palatine fossa and surrounds the pterygoid muscles It has important connections (a) with the cavernous sinus via the foramen ovale, (b) with the anterior facial vein via the deep facial vein, which passes with the buccal nerve and artery through the space bounded by the ramus of the jaw laterally and by the Buccinator medially, and (c) with the pharyngeal plexus of veins.

The plexus ends as a stem, the *internal maxillary vein,* which follows the artery deep to the neck of the jaw and joins the superficial temporal vein to form the posterior facial vein.

The Otic Ganglion is a parasympathetic ganglion—a relay station on the course of the *secretory fibers* of nerve IX (and nerve VII) to the parotid gland. The lesser superficial petrosal nerve brings the preganglionic fibers; the postganglionic fibers travel with the auriculo-temporal nerve (*figs. 713, 744*). *Motor fibers* from the mandibular nerve (via the n. to the Medial Pterygoid) pass through the ganglion en route to the Tensor Palati and Tensor Tympani. *Sympathetic fibers,* brought by the middle meningeal artery, pass through the ganglion.

The otic ganglion, about 3 mm. x 3 mm. in diameter, is situated below the foramen ovale, deep to the mandibular nerve. It is best seen (i.e., with least disturbance to its branches) from the interior of the pharynx after removal of the Tensor Palati.

THE MANDIBULAR OR JAW JOINT

The Bony Parts of the mandibular joint are: (a) the head or condyle of the jaw (b) the anterior part of the mandibular (articular) fossa of the temporal bone.

The posterior border of the ramus of the jaw expands above into a triangular process called the *neck,* the upper border or base of which is rounded like a roller, and is called the *condyle* or *head.* The condyle projects farther medially than laterally. The long axes of the condyles of opposite sides are not transverse, but are inclined postero-medially, and would, if produced, meet at the anterior border of the foramen magnum. In front of the neck is a *pit* for the tendon of the Lateral Pterygoid.

The *mandibular fossa* lodges the condyle and neck of the jaw and a process of parotid gland. It has an anterior articular part formed by the temporal squama and a posterior non-articular part formed by the tympanic plate. The two parts converge medially on the spine of the sphenoid, and they meet above at the squamo-tympanic fissure. The thin anterior edge of the tegmen tympani can be seen projecting into the medial part of the fissure.

The *articular part of the fossa* forms an oval socket for the condyle. It is situated immediately behind the roof of the infratemporal fossa and is separated from it by a rounded intervening border, known as the *articular eminence.* The articular eminence extends from the spine of the sphenoid to the tubercle of the

zygoma. Thus, it includes the anterior root of the zygoma. A small projection, the *postglenoid tubercle*, deepens the posterior part of the socket laterally.

The *non-articular part of the fossa* is formed by the *tympanic plate*. This square plate splits below to ensheath the styloid process. In front of it rests some fatty tissue or a process of the parotid gland.

The *roof* of the socket is translucent and thin; so, a blow on the chin may fracture the middle fossa of the skull. The *posterior wall* of the fossa (tympanic plate) is thin and it may be dehiscent; it would then allow pus to spread from the external meatus to the non-articular part of the fossa.

LIGAMENTS. The *strength* of the joint depends obviously on the bony conformation and on muscles. The *capsule* is necessarily lax, and posteriorly it is necessarily attached in front of the squamo-tympanic fissure, because through this fissure passes the tympanic branch of the maxillary artery. It is thickened laterally to form a triangular bundle, the *temporo-mandibular ligament*, the fibers of which pass downwards and backwards from the tubercle of the zygoma to the posterior border of the neck of the jaw. An *articular disc* caps the condyle and projects forwards under the articular eminence, dividing the joint cavity into an upper and a lower compartment. It is firmly fixed to the medial and lateral ends of the condyle; the capsule blends with its circumference and the tendon of the Lateral Pterygoid is partly inserted into its anterior margin.

Axiom. Articular discs imply two types of movement, one on each side of the disc. It is so at the sterno-clavicular, wrist, and knee joints, and is so here also. In the lower cavity simply hinge movements between the condyle and disc occur; in the upper cavity the disc and condyle together glide on the articular eminence. The disc is occasionally perforated.

TABLE 21

Movements of the Mandible

DEPRESS (OPEN MOUTH)	ELEVATE (CLOSE MOUTH)	PROTRACT (PROTRUDE CHIN)	RETRACT (WITHDRAW CHIN)	SIDE TO SIDE (GRINDING, CHEWING)
Digastric (anterior belly)	Temporal	L. Pterygoid	Temporal (postr. fibers)	Pterygoids of opposite sides alternately
Mylohyoid	Masseter			
Geniohyoid				
Infrahyoid muscles	M. Pterygoid			
Gravity				

PALPATION. The condyles can be palpated first by placing a finger in front of each tragus and then in each external auditory meatus, and their movements analyzed on opening and closing the mouth, on protruding and retracting the chin, and on performing grinding movements.

ACTIONS OF MUSCLES (Table 21). Gravity will open the mouth; but when opening against resistance, one can feel the infrahyoid muscles coming into action to fix the hyoid bone and the suprahyoid muscles (Geniohyoids, Mylohyoids, and anterior bellies of the Digastrics) depress the jaw. When masticating, the elevators obviously continue to act after the mouth is closed. Perhaps the Masseter and Medial Pterygoid assist in

protraction; and perhaps the Lateral Pterygoid assists in depression seeing its line of pull is above the axis of movement which passes through the mandibular foramina.

RELATIONS. *Laterally*—subcutaneous; *anteriorly*—insertion of Lateral Pterygoid; *posteriorly*—parotid gland, auriculotemporal nerve, and superficial temporal vessels; *medially*—the spine of the sphenoid which is crossed on its medial side by the chorda tympani and on its lateral side by the auriculo-temporal nerve and just in front of the spine is the foramen spinosum for the middle meningeal artery.

NERVE SUPPLY. V^3 via (a) auriculotemporal n. and (b) nerve to Masseter.

ACCESSORY BANDS. (1) The *spheno-mandibular ligament* is a vestige of Meckel's cartilage (1st visceral arch). It extends from the spine of the sphenoid to the lingula of the mandible.

(2) The *stylo-mandibular ligament* is a sheet of areolar tissue condensed between the parotid and submandibular glands, and connecting the styloid process to the angle of the mandible.

THE CERVICAL VERTEBRAE AND THE PREVERTEBRAL REGION

The Cervical Vertebrae. Man, the giraffe, and the mouse and, indeed, all other mammals (the manatee and certain sloths excepted) have seven cervical vertebrae. The 1st and 2nd are peculiar; the 3rd, 4th, 5th, and 6th are typical; the 7th is atypical. All have one distinguishing feature—their transverse processes are perforated.

A typical *body* is slightly elongated from side to side and is equal in height ventrally and dorsally. The upper surface resembles a shallow seat in having a raised lip at the back and sides and in being rounded in front. The inferior surface is the counterpart. The *pedicles* arise from the middle ⅓ of the side of the body; so, the upper and lower (inter) *vertebral notches* are of equal depth, moreover the pedicles project laterally as well as backwards; so, the *vertebral foramen* is triangular. The *laminae* are not specially noteworthy. The *articular processes* are placed at the junction of the pedicles and laminae. They form a bony column cut into oblique segments that permit flexion and extension of the neck, i.e., the lower rounded facet faces downwards and forwards and therefore can glide forwards on the upper facet of the process of the vertebra below. The *spinous process* is short, downturned, bifid, and V-shaped on cross-section. The *transverse processes* have two roots, a perforation, and two tubercles. The *anterior root* is a costal or rib element and like a rib it is attached to the side of the body and therefore is in front of the (inter)vertebral notch (*fig. 28*). The *posterior root* is a true or morphological transverse process and, as such, it is attached to the junction of pedicle and lamina and therefore is behind the (inter)-vertebral notch. The foramen transversarium transmits the vertebral artery; so, it is circular. It is closed laterally by a plate, the *costo-transverse bar*, which forms a gutter on which lies the anterior

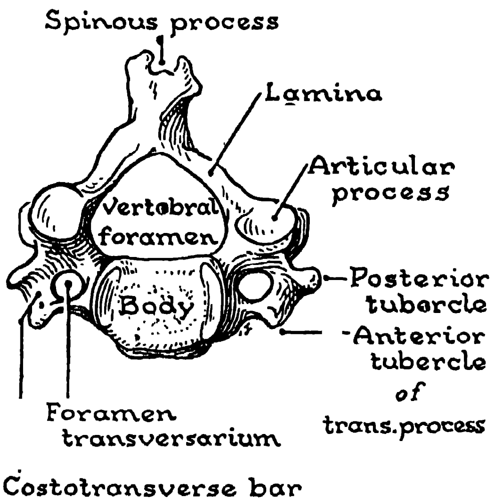


FIG. 698. A typical cervical vertebra, from above.

ramus of the spinal nerve that emerges from the intervertebral foramen, and its size varies with the ramus it supports. [The posterior ramus turns backwards in contact with the superior articular process.] The transverse processes are directed laterally and slightly downwards and forwards in conformity with the pull of the tendons attached to them and to the nerves resting on them. Muscles are attached to the posterior tubercles of all cervical vertebrae; but only the 3rd, 4th, 5th, and 6th have anterior tubercles (*figs. 637, 638*).

The 1st Cervical Vertebra supports the skull; so it is called the ***atlas.*** It loses its body and acquires an anterior arch. The lost body **becomes** the *dens* of the axis; so, it rotates around its own lost body. It also loses its spine, at least the spine is reduced to a tubercle, and so does not interfere with extension of the head (*fig. 699*).

The atlas is a ring divided into five equal arcs, viz., the anterior arch, right and left lateral masses, and a posterior arch composed of right and left halves. A transverse process projects from each lateral mass. The *anterior arch* is anterior to the dens and to the plane of the bodies of the other vertebrae. In embryonic life the other cervical vertebrae possess the mesodermal forerunner of an anterior arch, known as the *hypochordal bow* from its relationship to the notochord, but only in the atlas does this mature into a bony arch. The arch has a facet behind for the dens and a prominent tubercle in front to which the anterior longitudinal ligament and the right and left Longus Cervicis muscles ascend; so, it is downturned. The *tubercle* or *reduced spine* on the posterior arch gives attachment to two small muscles only, the right and left Recti Capitis Posteriores Minores (*fig. 639*); so, it is upturned and the *posterior arch* has no occasion to be strong. Further, it is flattened from above downwards and grooved for the vertebral artery, just behind the lateral mass. *Each lateral mass* has an upper and a lower weight-bearing facet. The upper facet articulates with the occipital condyle and, being its counterpart, is oval and concave, converges anteriorly on its fellow, and is partly subdivided into two. The lower facet articulates with the corresponding facet on the axis, is circular, and faces downwards and medially. A *tubercle* for the transverse ligament of the atlas, which retains the dens in position, projects medially from each mass. The *transverse process* projects laterally and being a lever that helps to rotate the atlas it is long—only lumbar transverse processes are longer. The *vertebral foramen* at this most movable part of the column is capacious, so, the cord is not liable to compression.

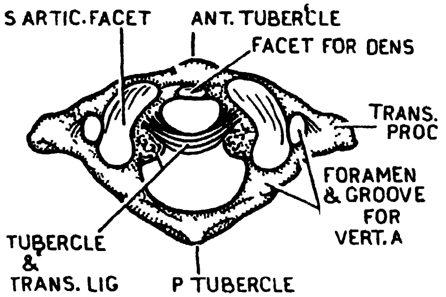


FIG. 699 The atlas transverse ligament of the atlas

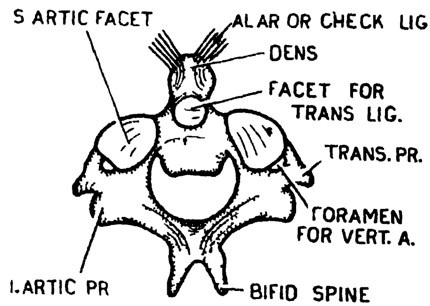


FIG. 700 The axis or epistropheus. (Postero superior view.)

At examinations the student commonly mistakes the lower aspect of the atlas for the upper.

The 2nd Cervical Vertebra or Axis is typical in its lower part and atypical in its upper. The *dens*, which projects from the upper surface of the body, is constricted at its root where the transverse ligament grips it, and it has a facet in front for the atlas. The ***superior articular***

facet being weight-bearing is large, and it extends out from the body on to the transverse process and covers the foramen transversarium. It lies entirely in front of the plane of the inferior articular process. The *transverse process* is short and downturned. The bifid *spine* is massive because large deep muscles (e.g., Multifidus, Semispinalis Cervicis) extend upwards to it--but no further—thereby leaving the atlas free to rotate around the dens whilst they are extending the vertebral column. The *vertebral arch*, from which the massive spine springs, must be massive too. The *vertebral foramen* must be large where movement is free, lest the spinal cord be damaged

THE 7TH CERVICAL VERTEBRA OR VERTEBRA PROMINENS has a long nonbifid spine—nearly as long as that of the first thoracic Its transverse processes are long and strong, the foramen transversarium transmits small veins and is often quite small

The pimple-like swellings on the anterior roots of the transverse processes of the atlas and axis and the pinpoint spine on the transverse process of C. 7 are homologous with anterior tubercles; so, the parts of the processes between these and the posterior tubercles are costo-transverse bars.

ANOMALIES. The articular processes of the occipital bone and atlas are occasionally fused; the axis and 3rd vertebra are commonly fused.

The tip of the dens may articulate with the margin of the foramen magnum.

The two sides of the p. arch of the atlas sometimes fail to make bony union.

The tips of the spines are non-bifid in lower races and anthropoids.

The 7th vertebra may carry cervical ribs—these are usually short; attached anteriorly by fibrous bands to the 1st ribs; and the subclavian arteries arch over them.

The Articulated Cervical Vertebrae, on front view. The bodies and transverse processes of the cervical vertebrae are nearly abreast of each other and, when clothed with the muscles attached to the anterior tubercles of the transverse proc-

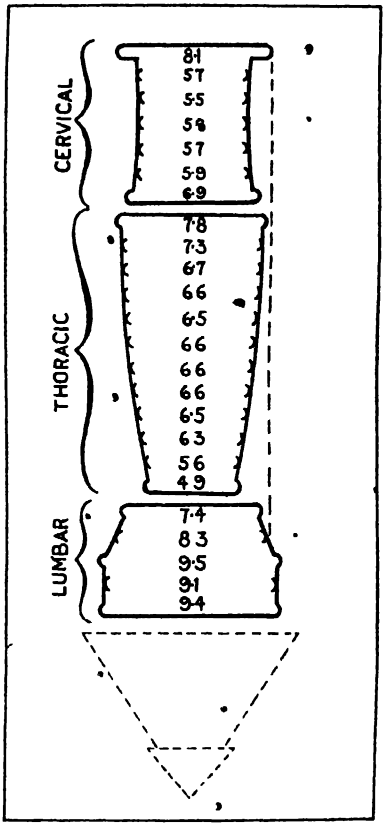


FIG. 701. Diagram showing the mean spread of the transverse processes (to scale).

esses, they present a relatively flat prevertebral surface. The basioccipital is above the anterior arch of the atlas and the jugular process (i.e., the transverse process) of the occipital bone is above the transverse process of the atlas. The 1st and 7th transverse processes project far beyond the 2nd–6th (*fig. 701*). All cervical transverse processes have

posterior tubercles, but only the 3rd, 4th, 5th, and 6th have anterior tubercles, and the 6th which is the most prominent of these is rendered doubly prominent by the absence of an anterior tubercle on the 7th.

Muscles of the Region grouped according to their relations to the cervical and brachial plexuses (*fig. 702*):

Muscles Medial to the Plexuses:

(1) Rectus Capitis Anterior
(2) Longus Cervicis
(3) Longus Capitis
(4) Scalenus Anterior

Muscles Lateral to the Plexuses:

(1) Rectus Capitis Lateralis
(2) Scalenus Medius and Posterior
(3) Levator Scapulae

The *Longus Cervicis* extends from the body of the 3rd thoracic vertebra to the anterior tubercle of the atlas, and it is attached to the bodies of the vertebrae in between. It sends slips to the 3rd, 4th, 5th, and 6th anterior tubercles and it receives slips from them, much as the Quadratus Lumborum does in the lumbar region. It extends therefore through most of the superior mediastinum and neck.

The *Longus Capitis* arises from the 3rd, 4th, 5th, and 6th anterior tubercles and ascends to the basiocciptal to be attached behind the plane of the pharyngeal tubercle. It fills the hollows between the bodies and transverse processes.

The *Scalenus Anterior* arises from the 3rd, 4th, 5th, and 6th anterior tubercles and descends to the scalene tubercle on the upper surface of the 1st rib between the groove for the subclavian artery and vein.

The *Rectus Capitis Anterior* covers the atlanto-occipital joint and extends from the front of the lateral mass of the atlas to the occipital bone in front of its condyle.

The *Rectus Capitis Lateralis* extends from the tranverse process of the atlas to the jugular process of the occipital bone.

The *Scalenus Medius* arises from all or most of the posterior tubercles of the transverse processes and descends to the upper surface of the 1st rib between the groove for the subclavian artery and the tubercle on the neck. The *Scalenus Posterior* is its most posterior part continued to the second rib behind the impression for the Serratus Anterior.

There is an angular gap between the transverse process of the atlas and the Scalenus Medius. This gap is occupied by the *Levator Scapulae*, which arises from the 1st, 2nd, 3rd, and 4th (posterior) tubercles and helps to form the muscle wall of the region.

Note that (a) structures descending from the jugular foramen cross in front of the Rectus Capitis Lateralis, the transverse process of the atlas, the Levator Scapulae, and either the Longus Capitis or Scalenus Medius, and the Scalenus Anterior. (b) Well developed Intertransverse muscles connect respective anterior and posterior tubercles. The Rectus Capitis Anterior and Rectus Capitis Lateralis represent modified Anterior and Posterior Intertransverse muscles, and the anterior ramus of C. 1 appears between them. (c) The jugular process is the transverse process of the occipital bone. (d) The Scaleni are modified Intercostal muscles, and (e) the brachial plexus represents enlarged and modified lateral branches of intercostal nerves piercing them (*fig. 88*).

The Prevertebral Fascia covers the prevertebral muscles and is continuous with the deep fascia that forms the carpet

for the posterior triangle of the neck (*p. 595*). It is part of a strong sleeve that envelops the deep muscles of the neck. brachial plexuses emerge from the vertebral column deep to the fascia, and of course the branches to the muscles

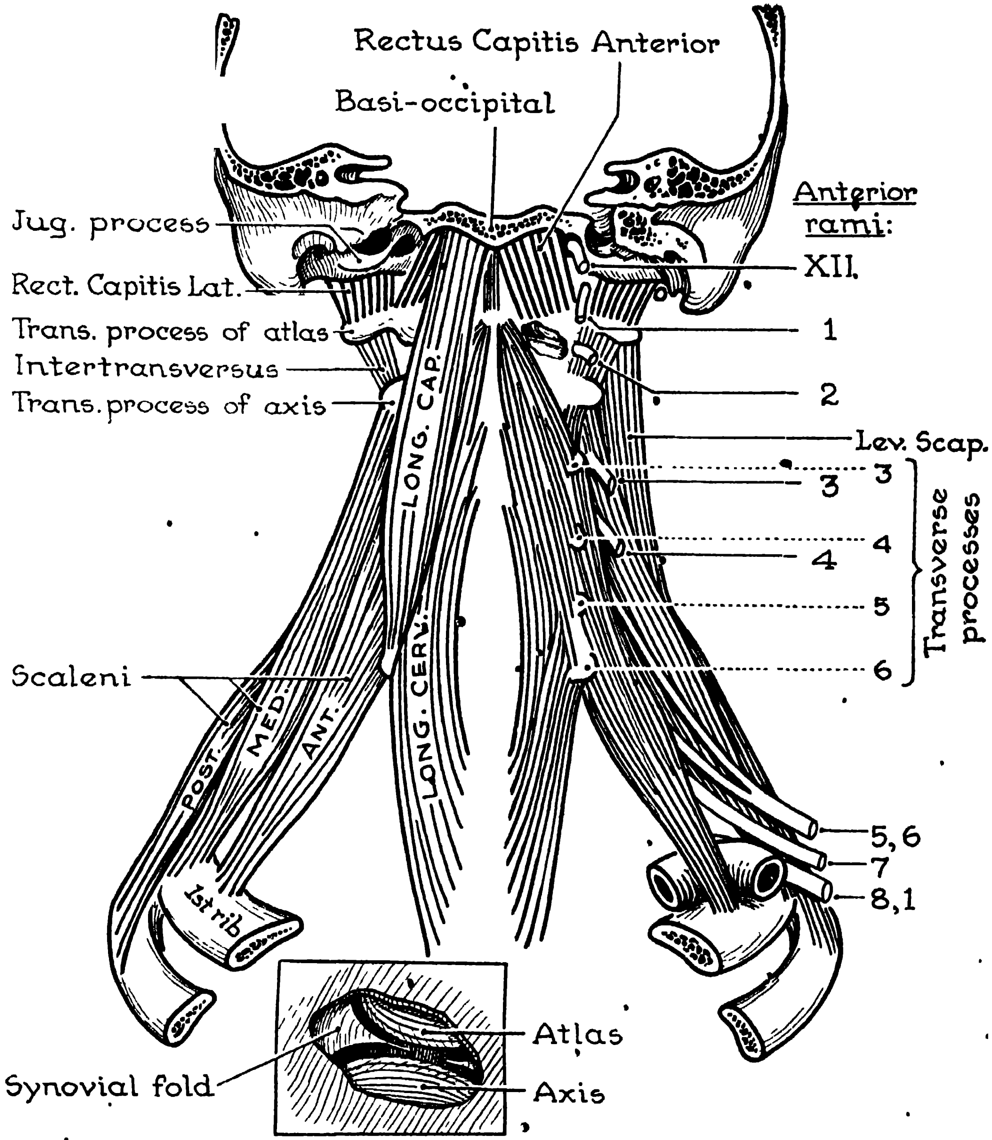


FIG. 702 The prevertebral muscles. The inserted figure shows synovial folds between the articular processes of atlas and axis.

It is attached above to the base of the skull behind the jugular foramen and it is lost below in front of the thoracic vertebrae. The roots of the cervical and described above and the phrenic nerve remain deep to it. The branches from the 2nd, 3rd, and 4th anterior rami to the accessory nerve, and from the 1st to the

hypoglossal nerve, and from the 2nd and 3rd to the ansa hypoglossi must pierce the fascia, so must all cutaneous branches namely, the lesser occipital (2), the great auricular (2, 3), the anterior cutaneus colli (2, 3), and the supraclavicular (3, 4). Gray rami communicantes passing from the sympathetic ganglia to the roots of the plexuses pierce the prevertebral fascia.

The Vertebral Artery. The vertebral artery is described as being the first branch of the subclavian artery, but there was a vertebral artery before the limbs appeared and before the subclavian

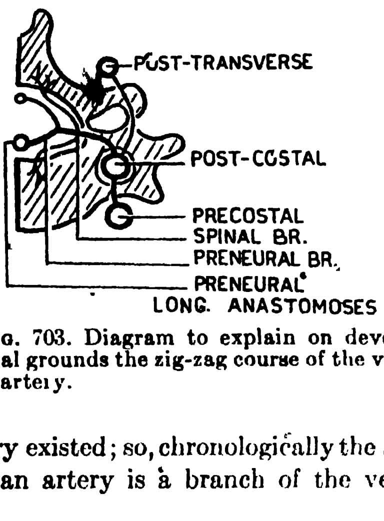


Fig. 703. Diagram to explain on developmental grounds the zig-zag course of the vertebral artery.

artery existed; so, chronologically the subclavian artery is a branch of the vertebral.

The zig-zag course taken by the vertebral artery is explained thus: The intercostal and lumbar branches of the aorta are typical somatic intersegmental arteries. Each gives off a posterior branch, which accompanies a posterior nerve ramus backwards between two transverse processes to supply the postvertebral region (*fig. 703*), and en route it sends a spinal branch through an intervertebral foramen to be distributed to the vertebral body, vertebral arch, membranes of the spinal cord, and the spinal cord itself. In the lower regions, this duty is performed by the ilio-lumbar and lateral sacral arteries; in the upper by the superior intercostal and vertebral arteries.

Developmentally, the intersegmental arteries in the neck are united by a series of longitudinally anastomosing vessels. one lying in front of the rib element (precostal), one behind it (postcostal), and one behind the transverse process (post-transverse). The first part of the vertebral artery is a branch of the 7th somatic intersegmental artery; the part ascending through the transverse processes is a postcostal longitudinal anastomosis; the part on the posterior arch of the atlas accompanying the 1st cervical nerve is a spinal branch. The vertebral arteries of opposite sides unite to form the *basilar artery* which is a preneural longitudinal anastomosis.

The *ascending cervical* and *superior intercostal arteries* represent precostal anastomoses; the *deep cervical artery* represents a post-transverse anastomosis.

The function of the vertebral artery is to supply the cervical segment of the cord and part of the brain.

Its *branches* in the neck are spinal and muscular, including branches to the suboccipital muscles.

Variant. The artery sometimes passes in front of the 6th transverse process and enters the 5th, 4th, or 3rd foramen.

A plexus of veins which begins in the suboccipital region surrounds the vertebral artery in its course through the transverse processes, emerges as a single vein, the *vertebral vein*, from the 6th process and ends in the innominate vein.

Anterior Rami of the Cervical Nerves. The cervical plexus is formed by the anterior rami of C. 1, 2, 3, 4; the brachial plexus by the anterior rami of C. 5, 6,

7, 8, and Th. 1. Ramus C. 4 sends a communication to ramus C. 5* and therefore is divided between two plexuses, just as L. 4 is divided between the lumbar and sacral plexuses, and S. 4 between the sacral and sacro-coccygeal plexuses.

The anterior rami of the lower 6 cervical nerves pass behind the vertebral artery, between Anterior and Posterior Intertransverse muscles, and appear between the Longus Capitis or Scalenus Anterior in front and the Scalenus Medius behind (*fig. 702*). The courses of nerves C. 1 and 2 are peculiar, due to the absence of "true" articular processes at the atlanto-occipital and atlanto-axial joints. Thus, the posterior root ganglia of C. 1 and 2 lie on the posterior arch of the atlas and axis respectively (*fig. 639*). Their posterior rami appear in the suboccipital region, one above and the other below the Obliquus Capitis Inferior. Their anterior rami curve forwards behind the superior articular processes of the atlas and axis respectively; that of C. 1 then passes medial to the vertebral artery, appears between the adjacent borders of the Recti Capitis Anterior and Lateralis, and descends in front of the anterior arch of the atlas; that of C. 2 then passes behind the vertebral artery and appears between (Anterior) and Posterior Intertransverse muscles. The anterior rami of C. 3–6 occupy the gutters on the 3rd, 4th, 5th, and 6th gargoyle-like transverse processes. C. 7 takes a similar course. These anterior rami increase in size from above downwards, so do the gutters in which they lie. The anterior rami of C. 8 and Th. 1 are related to the neck of the 1st rib: the former runs nearly horizontally above it, the latter ascends obliquely in front of it and they meet and unite at the medial border of the rib to form the lowest trunk of the brachial plexus. This trunk is in part responsible for the groove on the 1st rib commonly attributed to the subclavian artery.

The Joints between the Skull, Atlas and Axis. Five synovial joints are here involved, two paired and one median. The paired ones are between the articular processes of the atlas and axis and between the superior articular process of the atlas and the occipital condyles; the median unpaired one is between the dens and the anterior arch of the atlas. The first are plain joints, the second ellipsoidal, the third pivotal.

At the atlanto-occipital joints we nod our heads thereby indicating approval or the affirmative; at the atlanto-axial joints we shake our heads, thereby indicating disapproval or the negative. At the other cervical joints we flex and extend the neck and look sideways up. This last movement occurs also at the atlanto-occipital joints. The movements between the skull and atlas and between the atlas and axis have wide range, so, the ligaments of the vertebral arches and of the processes, being far from the centers of movement, are loose and weak. Even such a column of muscles as the Multifidus stops at the spine of the axis, leaving the atlas free to rotate. Near the centers of movement strong and peculiar ligaments appear, namely, the transverse ligament of the atlas and the alar ligaments.

Special Ligaments. The *transverse ligament* of the atlas is strong and flat, and extends between the tubercles on the lateral masses of the atlas. Though transverse it is of course not straight but arched. It passes behind the root of the dens and holds it forwards against the atlas. There is a synovial joint (a bursa) between the front of the dens and the

anterior arch of the atlas and a bursa (or synovial joint) between the back of the dens and the transverse ligament. The head of the dens is enlarged and cannot easily be withdrawn from its osseo-fibrous ring. Weak, upper and lower bands pass from the transverse ligament to the basi-occiput and body of the axis giving the whole a cruciate appearance (*figs. 699, 700*).

The *alar ligament* is a short, very stout cord (one on each side) that passes from the side of the apex of the dens upwards, axis to the inner surface of the basi-occipital spanning the atlas and cruciate ligament. It is broad and strong and called the *membrana tectoria.* The intervertebral disc between the dens (representing the atlas) and the basi-occiput persists as a vestigial thread, the *ligamentum apicis dentis*, which transmitted the notochord The supraspinous and interspinous ligaments form the *ligamentum nuchae*, a thin partition between the nuchal muscles which rises to the inion and external occipital crest. The liga-

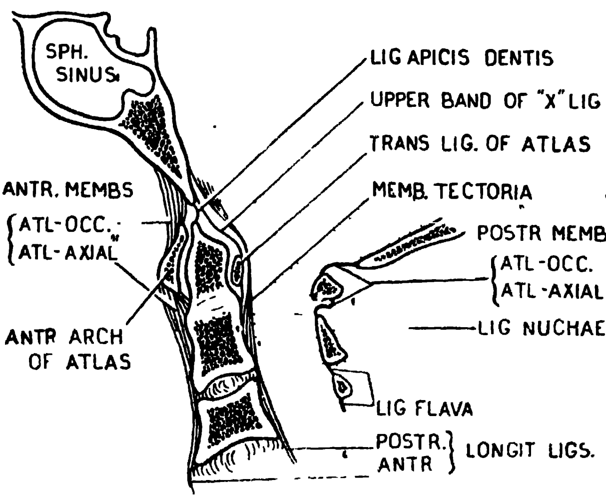


FIG. 701. Ligaments connecting the skull to the vertebral column (in median section).

forwards and laterally to the tubercle on the occipital condyle. They check rotation. A pair of less important special ligaments—the *accessory atlanto-axial*—takes the same direction as the alar ligaments and joins the lateral mass of the atlas to the body of the axis They check rotation also.

GENERAL LIGAMENTS (*fig 704*). The *anterior longitudinal ligament* becomes a cord at the axis and as a cord it continues to the anterior tubercle of the atlas and on to the basi-occipital bone. The *posterior longitudinal ligament* passes from menta flava become a weak closing *fibrous membrane* between occipital bone, atlas, and axis (see occipital region) behind the vertebral canal. The articular joints have loose capsules. The ligaments passing from the occipital bone to the vertebral column named from before backwards then are as follows: (a) the anterior longitudinal ligament, (b) ligamentum apicis dentis, (c) upper branch of cruciate ligament, (d) an alar ligament on each side, (e) membrana tectoria, (f) the posterior atlanto-occipital membrane and (g) the ligamentum nuchae.

The *short muscles* joining the upper cervical vertebrae to each other and to the occipital bone give security to the joint like the short muscles round the shoulder and the hip.

THE EXTERIOR OF THE BASE OF THE SKULL

The under surface of the base of the skull will be considered in 3 areas, (anterior, intermediate, and posterior) separated by an anterior and a posterior transverse line.

The Anterior Transverse Line is found by passing a pencil or straight wire through both mandibular notches and across the base of the skull. The fact that this can be done without the pterygoid laminae or plates obstructing is proof that they lie anteriorly (*fig. 705*).

On removing the mandible, the line is seen to cross (a) the foramen ovale at (b) the root of the lateral pterygoid lamina, (c) the foramen lacerum at (d) the root of the medial pterygoid lamina, and (e) the synchondrosis between the basi-occipital and basi-sphenoid, which fuses before the 25th year.

The Posterior Transverse Line unites the anterior margins of the right and left mastoid processes. It crosses (a) the tympano-mastoid fissure (between the mastoid and the orifice of the bony external auditory meatus) out of which the auricular branch of the vagus emerges, (b) the stylo-mastoid foramen between the styloid and mastoid processes, (c) the posterior margin of the jugular foramen, (d) the anterior condylar (hypoglossal) canal, and (e) the junction between the anterior ⅓ and posterior ⅔ of the occipital condyle. Features d and e lie on the synchondrosis line between the basilar and condylar parts of the occipital bone. This line will be observed to pass behind the ext. auditory meatus and to cross the anterior part of the foramen magnum (*fig. 773*).

The Anterior Area includes the follow-

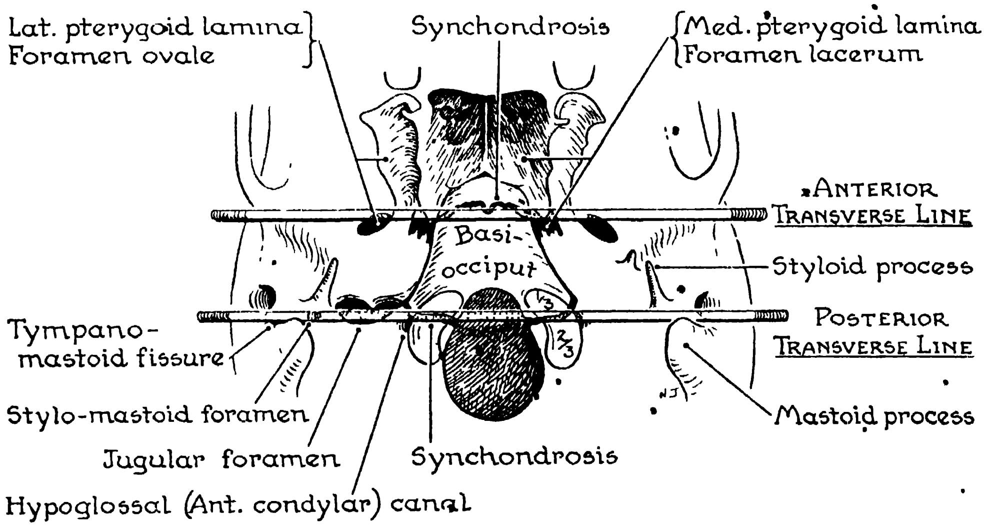


Fig. 705 The "anterior transverse line" and "posterior transverse line" on the exterior of the base of the skull.

ing: The *superior alveolar process*, generally U-shaped, carries 16 teeth, and has a free posterior end on each side, the *maxillary tuberosity* (*fig. 706*). The bony *palate* is bounded by the alveolar process except behind where it has a free crescentic border on each side separated by the *posterior nasal spine*. The bony palate is divided by a cruciate suture medial to the 3rd molar tooth and from it a groove runs forwards. The foramen is situated between the horizontal plate of the palatine bone and the alveolar process of the maxilla. The medial and lateral pterygoid plates end below freely between the level of the palate and the maxillary tuberosity; but, a portion of the palatine bone, the *tubercle* (*pyramidal process*),

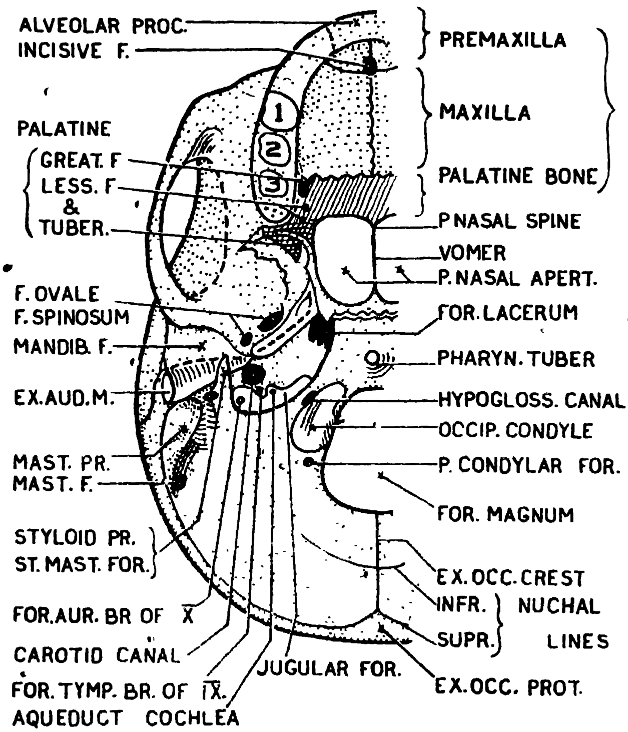


FIG. 706. The exterior of the base of the skull.

into an anterior $\frac{2}{3}$, the *palatine processes of the maxillae* and a posterior $\frac{1}{3}$, the *horizontal processes of the palatine bones*. On the sagittal limb of the suture, just behind the incisor teeth, the *incisive foramen* is situated. The remains of an irregular suture line, which runs from the incisive foramen to between the canine and the lateral incisor teeth, bounds the *premaxilla* posteriorly. The foramen of the *greater palatine canal* lies interposes itself like a buffer between the plates and the maxilla. Two branches of the greater palatine canal, known as the *lesser palatine canals*, descend through the tubercle.

THE POSTERIOR NASAL APERTURES (Posterior Choanae) are oblong and are twice as deep as they are wide ($1\frac{1}{2}$ x $\frac{3}{4}''$), but together they do not equal the hard palate in width. Each aperture is bounded on three sides by a sharp, free

edge belonging to the *medial pterygoid lamina*, the *horizontal plate of the palate bone*, and the *vomer*; and on the fourth side by the meeting of the *ala of the vomer* with the *vaginal process* of the medial pterygoid lamina below the body of the sphenoid.

THE PTERYGOID LAMINAE enclose the *pterygoid fossa* between them. The lateral lamina gives origin to the Lateral Pterygoid on its lateral surface and to the Medial Pterygoid on its medial surface It is, therefore, a muscular lamina and it is everted by the pull of the muscles The medial lamina is the hind part of the lateral wall of the nasal cavity. Its free border ends below in a hook, the *hamulus*, which is in echelon with the *maxillary tuberosity*, and the crown of the *3rd molar tooth* (*fig. 707*). It ends above conically as the *pterygoid tubercle* at the anterior border of the lower end of the foramen lacerum. Immediately lateral to it is the entrance to the *pterygoid canal*, which leads forwards to where the spheno-palatine ganglion is situated in the pterygo-palatine fossa. The superomedial part of the pterygoid fossa is continued towards the spine of the sphenoid as a *canoe-shaped fossa* (the scaphoid fossa) which gives origin to the Tensor Palati.

THE LOWER BORDER OF THE ZYGOMATIC ARCH is continued *anteriorly*, as a buttress to the second molar tooth, while *posteriorly*, as the anterior root of the zygoma, it turns medially and can be traced forwards as the infra-temporal crest towards the front of the inferior orbital fissure. The roof of the infratemporal fossa lies medial to the infratemporal crest.

The Intermediate Area. Medianly is the basi-occipital which widens as it passes backwards. Near its center, which lies above the anterior tubercle of the atlas, is the *pharyngeal tubercle* for the raphe of the constrictors of the pharynx. [From in front of the tubercle a sharp ridge running laterally and backwards on each side limits the insertions of the

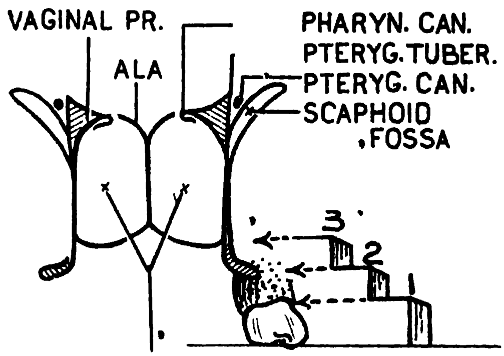


FIG. 707. Showing (1) the tuberosity of the maxilla, (2) the hamulus and (3) the hard palate in echelon

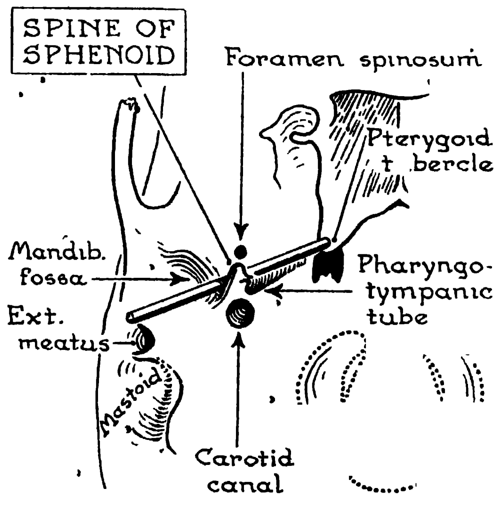


FIG. 708. The oblique line on the exterior of the base of the skull

Longus Capitis and Rectus Capitis Anterior.]

THE OBLIQUE LINE AT THE BASE OF THE SKULL (*fig. 708*). This imaginary line extends from the tubercle at the root of the medial pterygoid plate, which lies

on the anterior transverse line, to the front of the external auditory (acoustic) meatus. At the mid-point of this oblique line the *spine of the sphenoid* stands out like a sentinel that guards many strategic points. Thus, (a) anteriorly lies the foramen spinosum which transmits the middle meningeal artery; (b) posteriorly is the opening of the carotid canal; (c) medially is the orifice of the bony pharyngo-tympanic (auditory) tube, and a bristle entering here emerges through the external auditory meatus; and, (d) laterally is the mandibular fossa- indeed, the spine serves as a buttress to resist medial displacement of the head of the mandible, which occupies the fossa.

The half of the line antero-medial to the spine lodges the cartilaginous part of the pharyngo-tympanic (auditory) tube; the half postero-lateral is the squamo-tympanic fissure.

THE MANDIBULAR FOSSA (articular fossa) is the smooth, oval hollow in the temporal bone with which the head of the mandible articulates. It lies between the infratemporal fossa in front, the external auditory meatus behind, and the spine of the sphenoid medially. Therefore, this spine, the middle meningeal artery, and the carotid artery lie medial to the easily palpated head of the mandible. The anterior border of the fossa, being articular when the mouth is open, is rounded and is called the *articular eminence* (tubercle); its free lateral end is the anterior root of the zygoma. The square posterior wall of the fossa is the *tympanic plate.* At the upper limit of this plate is the *squamo-tympanic fissure.* It is the squamous part of the fossa (i.e., the part in front of the fissure) that is hollowed out for the mandible; this part is thin and translucent and may be fractured by a blow on the chin. The tympanic part is in contact with the parotid gland.

The thin anterior edge of the tegmen tympani, which forms part of the floor of the middle cranial fossa, projects into the medial part of the squamo-tympanic fissure, thereby dividing it into a *squamo-petrous fissure* and a *petro-tympanic fissure.*

At the lateral end of the fissure the squamous part of the temporal bone is prolonged downwards behind the head of the mandible as the *postglenoid tubercle* —in carnivora, that do not chew but use teeth as scissors, the tubercle descends far behind the head of the mandible.

THE CAROTID CANAL. The entrance to the carotid canal lies immediately behind the entrance to the bony ph-tymp. tube and is separated from the compartment for the jugular vein by a *bony wedge* on the apex of which there is a pinpoint opening for the *tympanic branch of the IX nerve* (*fig. 759*). The carotid canal curves upwards, forwards, and medially in the long axis of the petrous bone and opens into the foramen lacerum. The *styloid process* lies immediately lateral to the jugular fossa; its root may be smooth from contact with the jugular vein. A swelling on the jugular vein, the *jugular bulb,* excavates the *"roof"* of the jugular foramen (formed by the petrous bone) so that only a thin plate of bone separates it from the floor of the tympanum (*fig. 760*).

The Posterior Area is limited behind and at the sides by the inion, superior nuchal lines, and mastoid processes. It includes most of the foramen magnum, ⅔ of the occipital condyles, the jugular processes, and the nuchal portion of the occipital and mastoid bones. Its *features,* therefore, are: the grooves on the mastoid for the occipital artery and Digastric, the mastoid and posterior condylar fora-

mina, the inferior nuchal line, and the external occipital crest. The jugular process is homologous with the transverse process of the occipital bone. It is placed above the transverse process of the atlas and is joined to it by the Rectus Capitis Lateralis, which is homologous with a Posterior Intertransverse muscle.

THE GREAT VESSELS AND NERVES

The structures deep to the parotid region are:
(a) the internal jugular vein.
(b) the internal carotid artery.
(c) the last four cranial nerves.
(d) the sympathetic trunk

The complete cervical courses of these structures cannot be seen until the parotid and infratemporal regions have been dissected, and the posterior belly of the Digastric with its 2 associated arteries (occipital and posterior auricular), and the styloid process with its 3 attached muscles (Stylo-hyoid, Stylo-glossus, and Stylo-pharyngeus) have been severed and thrown aside.

General Dispositions. These deep and inaccessible structures enter or leave the skull through one of *three openings*:

1. Jugular foramen-- internal jugular vein, IX, X, XI nerves.
2. Hypoglossal canal-- XII nerve.
3. Carotid canal -internal carotid artery and sympathetic prolongations.

Where on the skull are these openings? Turn to the under aspect of the base of the skull and note that a line joining the front of one mastoid to the front of the other passes behind the styloid process, across the stylo-mastoid foramen, across the jugular foramen, across the hypoglossal canal, and divides the occipital condyles at the junction of their anterior $\frac{1}{4}$ and posterior $\frac{3}{4}$, in fact it separates the basilar part of the occipital bone from the lateral part. This key line is referred to in figure 705 and on page 703 as the "*posterior transverse line*".

The *jugular foramen* has 3 compartments: (a) a postero-lateral one for the internal jugular vein, (b) a middle one for nerves IX, X, and XI, and (c) an antero-medial one for the inferior petrosal sinus.

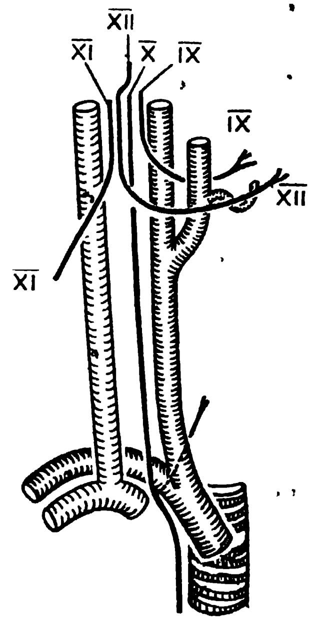


Fig. 709. The relations of the last four cranial nerves to the great vessels.

Now, the *hypoglossal canal*, which transmits the hypoglossal nerve, is separated from the jugular foramen by a bar of bone. But for this bar, all four nerves would traverse a single foramen.

The *carotid canal*, being an intra-osseous canal in the petrous-temporal bone, is obviously in front of the jugular foramen, which is an interosseous foramen between the petrous temporal and occipital bones. Hence, at the base of the skull the internal carotid artery lies in front of (and slightly medial to) the internal jugular vein, and the wedge of temporal bone between

them is thin. The four nerves lie medially in the angle between the artery and vein. *These vessels and nerves and the sympathetic trunk are compactly placed together (fig. 720).*

All *four nerves* descend together for a short distance between the internal jugular vein and the internal carotid artery (*fig. 709*). The X or *vagus nerve* continues perpendicularly through the neck between the great artery and vein. The IX or *glosso-pharyngeal nerve*, in order to reach the pharynx and posterior third of the tongue, passes forwards superficial to the internal carotid artery; the XI or *accessory nerve*, in order to reach the Sterno-mastoid, passes backwards superficial to the internal jugular vein. The XII or *hypoglossal nerve*, in order to reach the tongue, passes forwards superficial to the internal and external carotid arteries.

The Superficial Relations of the Carotid Sheath. If you set yourself the question, "What structures would I require to remove, cut through, or displace in order to display the common and internal carotid arteries, the internal jugular vein, and the vagus nerve as they pass through the root of the neck, carotid-triangle, and the deep part of the neck enveloped in the carotid sheath?", you are best to tackle it in orderly fashion, preferably by layers; otherwise you are more than likely to omit important structures. You will select the appropriate items from the following possibilities:

1. Platysma.
2. Superficial nerves.
   Sensory: Great auricular, and anterior cutaneous of the neck.
   Motor: Facial nerve and branches.
3. Superficial veins.
4. Deep fascia—one or more layers.
5. *Muscles:*
   Suprahyoid: Posterior belly of Digastric and 2 associated arteries; Styloid process and 3 attached muscles; Anterior belly of Digastric and Mylohyoid.
   Infrahyoid: Sterno-hyoid, Omohyoid, Sterno-thyroid, and Thyrohyoid (in line with the Rectus Abdominis) and their nerves derived from the hypoglossal and ansa hypoglossi nerves.
   Sterno-mastoid.
6. *Arteries:* Branches of the external carotid that run backwards, (occipital and posterior auricular) mentioned above with the Digastric, and sterno-mastoid branches of the occipital and superior thyroid arteries.
7. *Veins:* Tributaries of the internal jugular vein running backwards.
8. *Nerves:* IX and XII running forwards; XI running backwards; X and its cardiac branches running downwards and its pharyngeal, superior laryngeal, and (on the right side) the recurrent nerve running forwards. The sympathetic trunk and branches. The descendens hypoglossi and descendens cervicalis.
9. *Glands:* Lymph, salivary (submandibular, parotid), thyroid, parathyroid, and thymus.
10. Variations due to sex, age, and race nil.
11. *Anomalies:* The thymus gland, the left innominate vein, and (right) innominate artery may be in part cervical. The thyroid gland may be in part retrosternal. The connecting vein between the common facial and anterior jugular veins may be very large. The thoracic duct very rarely ends on the right side. Nerves XI and the cervicalis descendens sometimes cross deep to the internal jugular vein.

The Common and Internal Carotid Arteries (*fig. 710*). This great arterial stem, the internal jugular vein, and the

vagus nerve travel through the neck enveloped in the carotid sheath. The artery is medial, the vein lateral, and the nerve is posterior in the angle between them. The sympathetic trunk runs through the neck behind the artery, but it is outside the carotid sheath.

MEDIAL RELATIONS. As this arterial stem travels through the neck from sterno-clavicular joint to carotid canal, it is applied to the side of the digestive and respiratory tubes. The width of the oesophagus (25 mm.) separates the right and left common carotids at the root of the neck; the width of the pharynx, which is twice that of the oesophagus, separates the right and left internal carotids where they enter the carotid canals at the base of the skull (52 mm. apart); so, they diverge as they ascend.

The rounded posterior border of the *thyroid gland* usually insinuates itself between the common carotid artery and the oesophagus, trachea, and recurrent nerve and forces the artery laterally.

The common carotid artery divides into internal and external carotid arteries about the level of the upper border of the thyroid cartilage. Just above the bifurcation of the common carotid, the external carotid lies between the internal carotid and the pharyngeal wall. The *superior laryngeal nerve* always passes between the internal carotid a. and the pharynx.

[In this description the pharyngeal fascia, pharyngeal plexus of veins and nerves, the ascending pharyngeal artery and the ascending palatine and the tonsilar branches of the facial artery are considered as constituents of the pharyngeal wall—which they are.]

The internal carotid artery gives off no branches in the neck. It may be tortuous; it may even describe a loop which brings it close to the tonsil. At its origin there is a fusiform dilatation, the *carotid sinus*. The sinus is a blood pressure regulating mechanism which receives twigs from the glosso-pharyngeal nerve and also from the vagus and sympathetic.

Separating the external carotid from the internal carotid are the following:

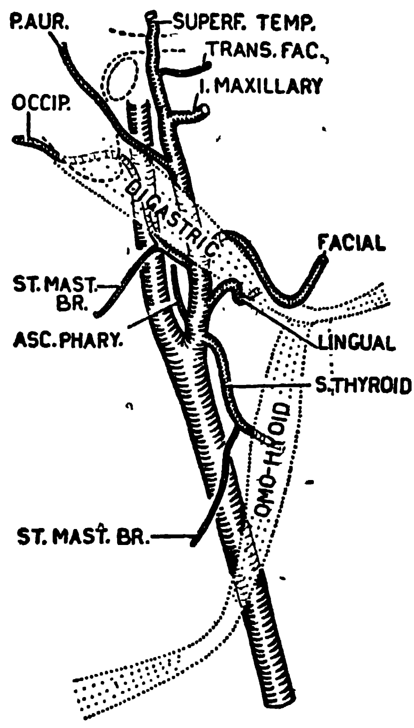


FIG. 710. The three carotid arteries and the branches of the external carotid artery.

(a) The styloid process, the Stylo-pharyngeus, and the Stylo-glossus, but not the Stylo-hoid which, being a derivative of the Digastric, passes superficial to both arteries.

(b) The glosso-pharyngeal nerve and pharyngeal branches of the vagus. [The superior laryngeal nerve or else its internal and external branches pass medial to both carotid arteries for reasons given in figure 715].

(c) A portion of the parotid gland.

Posterior Relations. The great arterial stem may be compressed against the prominent carotid tubercle of vertebra C. 6 (*fig. 679*).

Below the tubercle, the beginning of the subclavian artery and the vertebral artery and vein lie behind the great arterial stem; and the inferior thyroid artery and the thoracic (or right lymph) duct cross between the carotid sheath and the vertebral vessels; on the right side, the right recurrent nerve is also a posterior relation.

Above the tubercle, the prevertebral fascia and prevertebral muscles separate the artery from the transverse processes. At the base of the skull the last four cranial nerves are behind the artery. The sympathetic trunk is posterior throughout, except below, where it crosses the subclavian artery.

Lateral Relations. Laterally are the internal jugular vein and the vagus nerve. The vein is behind at the jugular foramen and somewhat in front where it ends in the innominate vein, elsewhere it is overlapping. Cardiac branches of the vagus and sympathetic accompany the artery (*figs. 668, 675*).

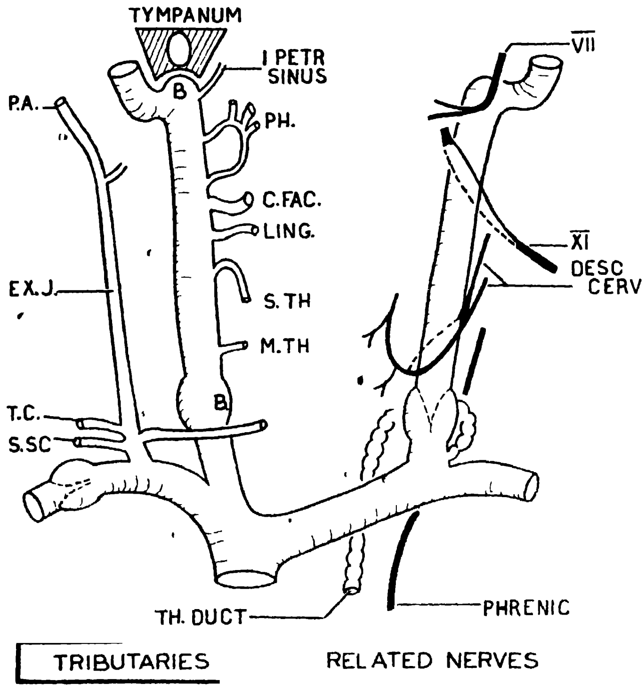


FIG. 711 The internal jugular vein.

The Internal Jugular Vein (*fig. 711*) is the continuation of the sigmoid sinus. It begins at the jugular foramen and ends, just after crossing in front of the first part of the subclavian artery, by joining the subclavian vein to form the innominate vein. The point of union is separated from the sterno-clavicular joint by two infrahyoid muscles.

Bulbs. The vein has a swelling or bulb at each end: *The upper bulb* which is an outpouching from the wall of the vein, the size of the tip of a finger, ex-

cavates the roof of the jugular foramen and is separated from the floor of the tympanum merely by a thin plate of bone. The bulb is usually larger on the right side because the superior sagittal sinus usually turns to the right.

The lower bulb is a dilatation of the vein below the bicuspid valve situated about half-an-inch above the clavicle.

At the base of the skull the vein lies on the *posterior transverse line* (*fig. 705*). It is deep to the stylo-mastoid foramen and therefore deep to the facial nerve and stylo-mastoid branch of the posterior auricular artery; it is behind the carotid canal and therefore behind the internal carotid artery and the cranial prolongations of the sympathetic trunk; and it is postero-lateral to the last four cranial nerves.

The vein occupies the lateral part of the carotid sheath. It is separated by the prevertebral fascie from the more lateral of the prevertebral muscles and the cervical plexus (*fig. 712*). [Thus, it crosses Rectus Capitis Lateralis, transverse process of the atlas, Levator Scapulae, Scalenus Medius and cervical plexus, Scalenus Anterior and phrenic nerve.]

At the root of the neck it crosses (a) the first part of the subclavian artery and some of its branches (vertebral, internal mammary, thyro-cervical, and costo-cervical), (b) the phrenic and vagus nerves separated from each other by the thyro-cervical artery; (c) the thoracic or right lymph duct, which passes between the carotid sheath and the vertebral vessels, and (d) it makes contact with the cervical pleura. The precise posterior relations vary with the state of engorgement of the vein.

The accessory nerve and the descendens cervicalis nerve (C. 2, 3) pass either anterior or posterior to the vein (*fig. 711*).

Tributaries. (a) The first tributary and the last, not being veins, are apt to be overlooked (*fig. 711*). They are the *inferior petrosal sinus* and the *thoracic duct* or the *right lymph duct.* These enter the extreme upper and lower ends respectively of the internal jugular vein. (b) The *middle thyroid vein* joins the internal jugular vein in the muscular triangle. It has no companion artery. (c) The 4 other tributaries accompany, more or less closely, certain of the six collateral and two terminal branches of the external carotid artery, and they are named accordingly. That is to say, 4 names are to be chosen from the following list of 8 arteries: superior thyroid, lingual, facial, occipital, posterior auricular, ascending pharyngeal, and internal maxillary and superficial temporal.

The chosen ones—*superior thyroid, lingual*, and *common facial veins*—join the internal jugular vein below the level of the hyoid bone; the *pharyngeal vein* or veins joins it deep to or above the Digastric. The *occipital vein* ends either in the vertebral plexus of veins or in the internal jugular vein.

The terminations of the *posterior auricular, int. maxillary*, and the *superficial temporal veins* are shown in figure 628.

The Last Four Cranial Nerves (Extra-cranial Course). The general dispositions of these four nerves on leaving the skull are given on page 708. At the base of the skull *nerves IX and X* possess two ganglia each, an upper and a lower. These ganglia are the equivalent of posterior root ganglia to spinal nerves and of the trigeminal ganglion to nerve V. Both nerves conduct efferent and afferent impulses to and from viscera. *Nerves XI and XII* conduct efferent

impulses only, their fibers supplying striated muscles, and both receive contributions from the anterior rami of the upper cervical nerves

mater. It descends between the internal jugular and internal carotid vessels to the posterior border of the Stylo-pharyngeus and, winding around it, passes forwards between the internal and external carotids. It then follows the upper border of the Middle Constrictor deep to the Hyoglossus and so enters the pharynx

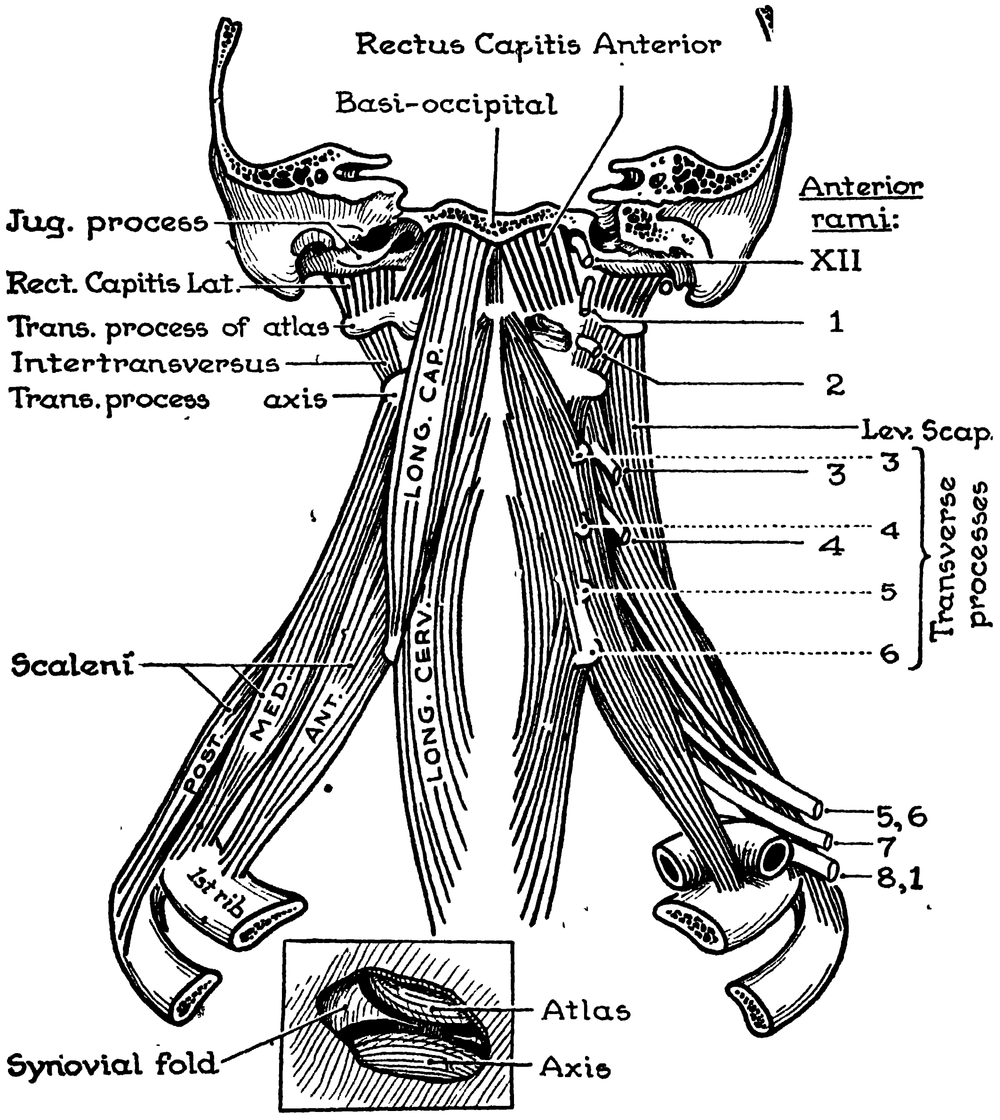


FIG 712. The prevertebral muscles—to explain the posterior relations of the internal jugular vein.

The Glosso-pharyngeal Nerve (IX) (*fig. 713*) leaves the skull through the jugular foramen with the vagus and accessory nerves, but in its own sheath of dura

where it spreads out submucously over the posterior third of the tongue.

Distribution: Its one *motor* branch supplies the Stylo-pharyngeus. Fibers of *general sensation* pass to the pharyngeal plexus—which is formed on the Middle Constrictor by branches of the vagus, sympathetic, and glosso-pharyngeal—and through it supply the greater part of the pharyngeal wall. One branch, the *sinus nerve,* consists of the afferent fibers from the carotid sinus and carotid body; when stimulated it brings about a reduction of the blood pressure

The terminal fibers spread over the posterior third of the tongue, extending beyond the vallate papillae as fibers of general sensation and of *taste* (*fig. 730*); other branches are sensory to the tonsil, pharyngeal arches, and soft palate These fibres initiate the swallowing reflex.

The *tympanic branch* passes into the tympanum through the minute canal or the apex of the wedge between the carotid canal and jugular foramen; it is sensory to the pharyngo-tympanic tube, tympanum, medial surface of the ear drum, tympanic antrum, and mastoid air cells. It is joined in the tympanum by sympathetic twigs from around the carotid artery It leaves the tympanum and in the petrous bone is joined by a twig from the facial ganglion (geniculate) to form the *lesser superficial petrosal nerve,* which passes to the otic ganglion, there to be relayed via the auriculo-temporal nerve to the parotid gland as its *secretory nerve.*

The Vagus Nerve (X). This vagrant or wandering nerve (*fig. 714*) leaves the skull through the middle compartment of the jugular foramen in the same sheath of dura mater as nerve XI. It descends through the *neck* within the carotid sheath, occupying the posterior angle between the internal jugular vein and the great carotid stem as far as the sterno-clavicular joint. There it crosses behind the respective innominate vein to enter the superior mediastinum.

In the Superior Mediastinum the courses are subpleural, but they differ on the two sides (*fig. 603*). *On the right side,* the vagus, having crossed the subclavian artery (IV primitive aortic arch), de-

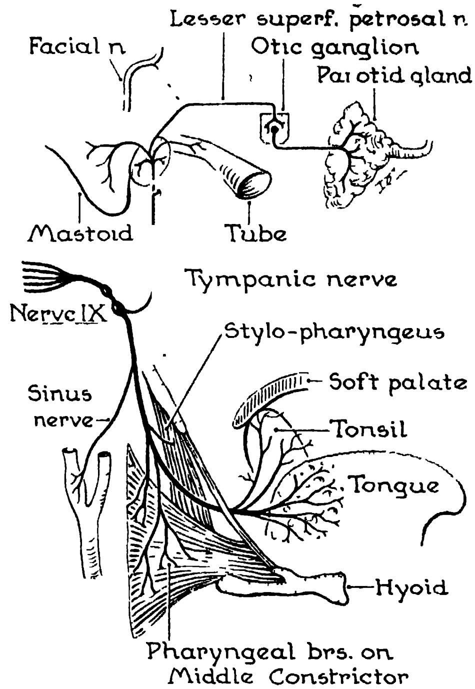


FIG. 713. Distribution of the glosso-pharyngeal (IX) nerve.

scends to the back of the root of the lung, lying first on the side of the innominate artery, and then on the trachea. *On the left side,* the vagus continues its descent along the side of the carotid artery to the aortic arch (IV primitive aortic arch) and the subclavian artery lies posteriorly. It crosses the left side of the arch to reach the back of the root of the lung.

In the Posterior Mediastinum the courses are similar on the two sides. Each nerve

forms a posterior pulmonary plexus, from which one or two stems emerge and pass

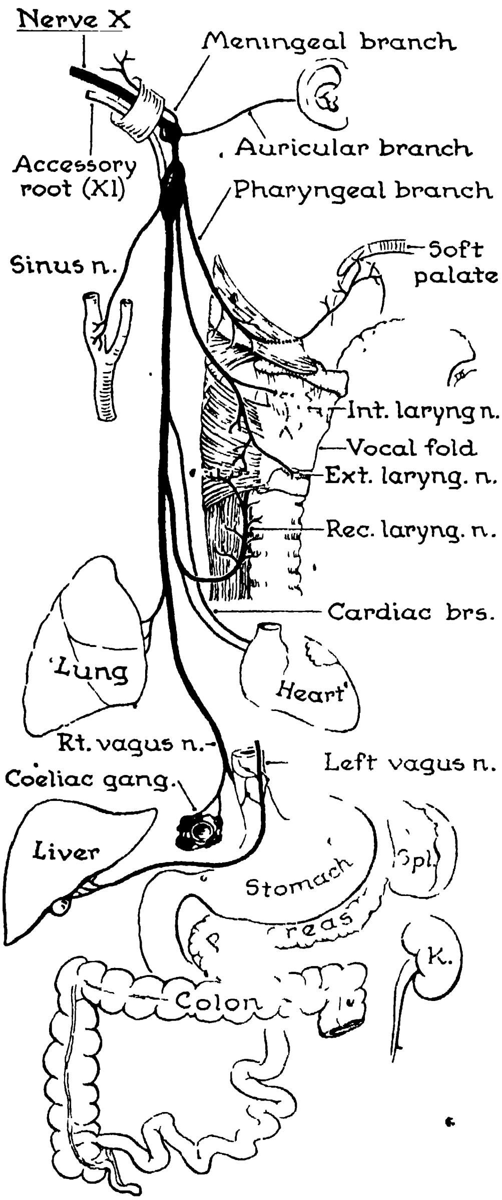


FIG. 714. Distribution of the vagus (X) nerve.

to the oesophagus (the right nerve to the back, the left nerve to the front), where they form the oesophageal plexus around the oesophagus. From the plexus an anterior and a posterior gastric nerve emerge and descend on the respective surfaces of the oesophagus, through the oesophageal opening in the diaphragm, to the stomach.

In the Abdomen the two nerves lie close to each other at the lesser curvature of the stomach. The anterior (left) gastric nerve supplies the anterior surface of the stomach, and sends branches to the liver, pylorus, first part of the duodenum, and pancreas; the posterior gastric nerve supplies the posterior surface of the stomach and sends one or two large branches in company with the stem of the left gastric artery to the celiac plexus, whence it is distributed with the blood vessels to the intestine as far as the left colic flexure and to the other abdominal viscera.

Of the *two ganglia* of the vagus, the superior (jugular) is small, the inferior (nodosum) is an inch long and lies just below the base of the skull. The cranial or *accessory root* of the spinal accessory nerve joins the vagus at and beyond the ganglia and brings to it the motor fibres for the muscles of the pharynx, soft palate, and larynx.

BRANCHES arise from the vagus thus:

In the jugular fossa:
  Meningeal and auricular.

In the neck:
  Pharyngeal, superior laryngeal, sinus, cardiac, and right recurrent laryngeal.

In the thorax:
  Cardiac, left recurrent laryngeal, pulmonary, and oesophageal.

In the abdomen:
  To most abdominal viscera.

The ***meningeal twigs*** are distributed to the dura mater of the posterior cranial fossa. The ***auricular branch*** crosses behind the jugular vein and enters a canal in

the lateral wall of the jugular fossa, which conducts it past the facial nerve to the tympano-mastoid fissure, through which it emerges, and supplies the outer surface of the tympanic membrane, and the adjacent parts of the external auditory meatus. It also sends twigs to the back of the ear (auricle).

In the neck, the chief duty of the vagus is to supply the alimentary and respiratory tubes. This it does via 3 branches: pharyngeal, superior laryngeal, and recurrent laryngeal. In the embryo, these three pass between the primitive ventral and dorsal cephalic aortic arches (*fig. 715*). Post-natally, the glosso-pharyngeal nerve continues this course. With the breaking down of the segment of the primitive dorsal aorta between the 3rd and 4th arches, the *superior laryngeal nerve* is enabled to rise to a higher level and to slip behind the internal and external carotids. On the disappearance of the right 5th and 6th primitive aortic arches, the *right recurrent laryngeal nerve* rises to the 4th primitive arch (subclavian artery), recurs below it, and passes behind the common carotid artery. The *left recurrent laryngeal nerve* continues its original course round the primitive 6th arch (the ductus arteriosus).

The *pharyngeal branch* pierces the Superior Constrictor and supplies all the voluntary muscles of the pharynx and soft palate, except the Stylo-pharyngeus and Tensor Palati.

The *superior laryngeal nerve* passes medial to the internal and external carotids and, lying on the Middle Constrictor, divides into an internal and an external branch; the *internal branch* pierces the thyro-hyoid membrane and is sensory to the larynx above the level of the vocal cords and to the region around the aperture of the larynx (*p. 766*); the *external branch*, after partly supplying the Inferior Constrictor, ends in the Crico-thyroid.

The *recurrent laryngeal nerves:* the *right nerve* arises from the vagus where it crosses in front of the subclavian artery. It recurs below the subclavian and is there in contact with cervical pleura; it then crosses behind the common carotid artery and ascends in the angle between the trachea and oesophagus as described

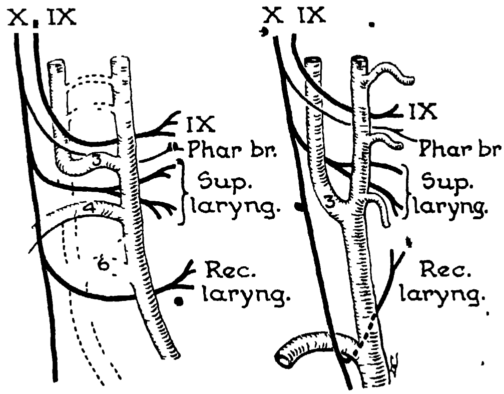


FIG. 715. Developmental explanation of the relationship of the glosso-pharyngeal, superior laryngeal, and recurrent laryngeal nerves to the carotid arteries. In about 1 per cent of persons the right subclavian a. arises from the aorta (see fig. 593), the recurrent nerve then does not recur around the 4th arch but, like the superior laryngeal nerve, takes a direct course.

on page 673. The *left nerve* arises from the vagus where it crosses the aortic arch. It recurs around the lig. arteriosum, passes below and medial to the aortic arch and may there be surrounded by tracheo-bronchial lymph glands. It then ascends in the angle between the trachea and oesophagus, as on the right side. *Both recurrent laryngeal nerves* give off cardiac, oesophageal, and tracheal branches and branches to the Inferior Constrictor. They supply all the muscles of the larynx (the Crico-thyroid excepted), and they are sensory to the larynx below the vocal cords.

A branch of the vagus passes to the *carotid sinus* and carotid body.

Cardiac branches are described on page 562; *pulmonary* branches on page 516.

DISTRIBUTION. The vagus supplies (a) the *voluntary muscles* of the pharynx (except Stylo-pharyngeus), soft palate (except Tensor Palati), and larynx; (b) the *heart* muscle, and the *involuntary muscle* of the oesophagus, stomach, and

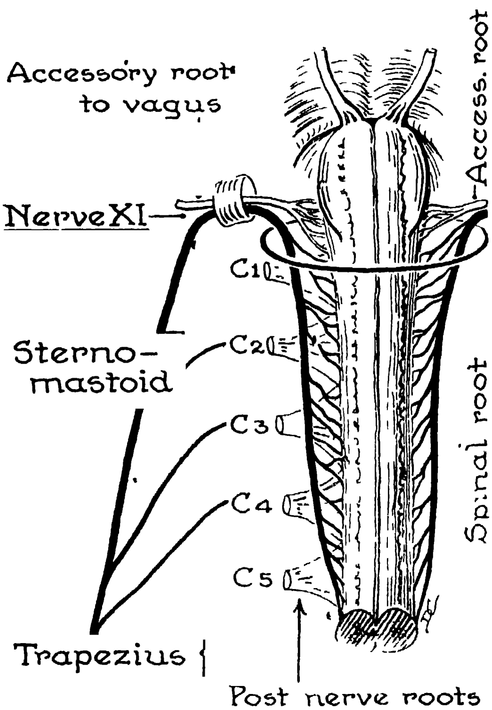


FIG. 716. Origin and distribution of the accessory (XI) nerve.

intestines down to the left colic flexure, and the gall bladder; and it contains (c) the *secretory* fibers for these organs. It contains (d) *afferent* fibers from these organs and from the larynx and lower respiratory passages, and (e) a few *taste* fibers from the region of the epiglottis.

The Accessory or Spinal-accessory Nerve (nerve XI) (*figs. 716, 720*) has a *double origin—spinal* and *cranial*. The *spinal root* arises from the anterior gray column of the upper five or six segments of the spinal cord, ascends behind the lig. denticulatum, and enters the posterior cranial fossa through the foramen magnum. The *cranial or accessory root* arises from the nucleus ambiguus, and leaves the medulla behind the olive as several fila in line with those of the vagus. The two roots unite as they enter the middle compartment of the jugular foramen (within the same dural sheath as the vagus), and as they leave the foramen, they separate.

The *cranial part* at once joins the vagus, bringing to it fibers for the supply of the voluntary muscles of the pharynx, soft palate, and larynx (*p. 766*). Hence, this part is accessory to the vagus.

The *spinal part* courses downwards and backwards in front of the internal jugular vein (or behind it) and the transverse process of the atlas. It makes a brief appearance in the carotid triangle between Digastric and Sterno-mastoid. Surrounded by lymph glands, and accompanied by the sterno-mastoid branch of the occipital artery, it enters the deep surface of the Sterno-mastoid 1½" 2½" below the tip of the mastoid process. It next appears at the posterior border of the Sterno-mastoid near its mid-point and here again it is surrounded by lymph glands. Lying on the Levator Scapulae, it crosses the posterior triangle immediately subjacent to the deep fascia, above and parallel to branches of C. 3 and 4 (*fig. 628*). It passes under cover of the anterior border of the Trapezius two or three fingers' breadth above the clavicle. Continuing deep to the Trapezius it crosses the medial angle of the scapula (*fig. 73*).

Distribution. The accessory nerve supplies the Sternomastoid and Trapezius. Within the Sternomastoid it is joined by a branch of C. 2, and deep to the Trapezius by branches of C. 3 and 4, but these

cervical branches are entirely sensory (K. B. Corbin).

The Hypoglossal Nerve (nerve XII) (*fig. 717*) emerges from its canal between the atlanto-occipital joint and the jugular foramen. It descends, making a half spiral turn behind the vagus and picking up a branch from C. 1. It continues between the internal jugular vein and internal carotid artery to the lower border of the Digastric and Stylo-hyoid and so enters the carotid triangle. There it hooks round the occipital artery and, while doing so, gives off its *descendens branch*. It makes a gentle loop downwards and forwards superficial to the "arterial plane" (i.e., the plane of the 3 carotid arteries and the 3 forward branches called s. thyroid, lingual, and facial) and, passing deep once again to the Digastric and Stylo-hyoid, it enters the digastric triangle. There concealed by the submandibular gland, it continues forwards superficial to the Hyoglossus, which now separates it from the lingual artery, and passes deep to the free posterior border of the Mylohyoid. Arriving at the anterior border of the Hyoglossus it swings medially and its branches ascend in the substance of the tongue.

Distribution. The hypoglossal nerve supplies all 3 extrinsic muscles of the tongue (Stylo-glossus, Hyo-glossus, Genio-glossus) and all the intrinsic muscles. The contribution from C. 1 is distributed as the descendens hypoglossi, the branch to the Thyro-hyoid and the branch to the Genio-hyoid.

The last four cranial nerves effect numerous other connections at the base of the skull. As the significance of many of these is not known, the labor of committing their details to memory would be neither wise nor profitable.

The Sympathetic Trunk. The cervical portion of the sympathetic trunk passes through the neck behind the common and internal carotid arteries, but outside the carotid sheath. It is medial to the vagus, which lies between the carotid and jugular vessels inside the carotid sheath. It is also thinner than the vagus, except at the sites of its three ganglia. The *superior ganglion*, is about

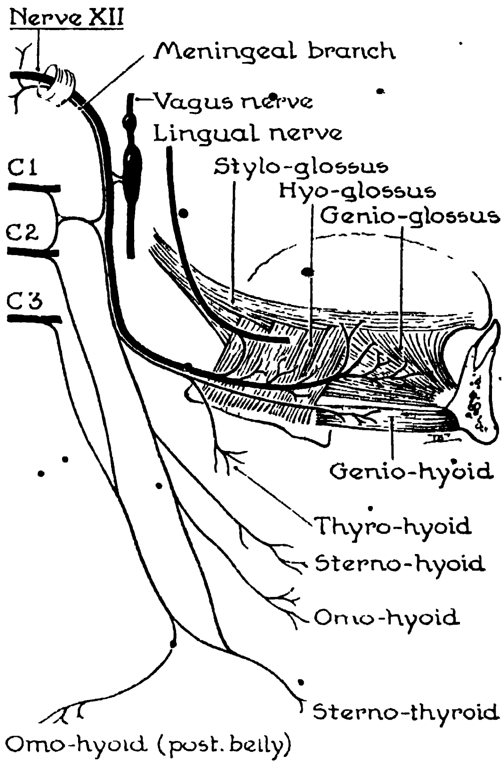


FIG. 717. Distribution of the hypoglossal (XII) nerve.

two inches long. It extends downwards to the level of the greater horn of the hyoid. The *middle ganglion*, the size of a pin's head, lies in front of the inferior thyroid artery below the level of the cricoid; commonly it is in two parts (*p. 667*). The *inferior ganglion*, large flat and nodular, lies in front of the 7th cervical transverse process behind the vertebral artery, but commonly it fuses in front of

the neck of the first rib with the first thoracic ganglion to form the *stellate ganglion.*

The trunk sends a loop around the inferior thyroid artery, another around the vertebral artery, and another around the subclavian artery (ansa subclavii).

BRANCHES (*fig. 718*). There being no white rami communicantes in the cervical region, the cervical sympathetic trunk

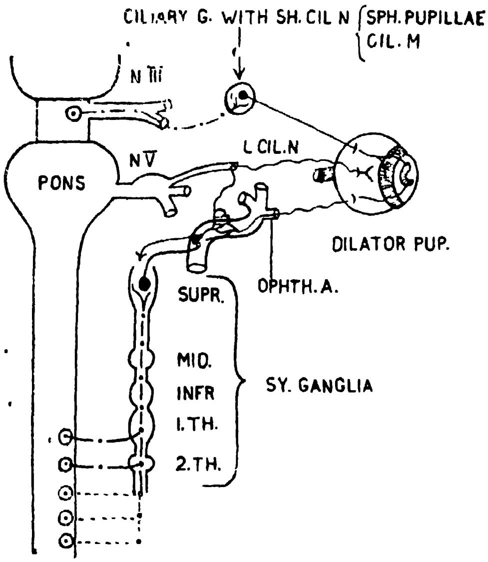


FIG. 718. The sympathetic trunk in the neck.

derives its fibers chiefly from the upper two thoracic segments. It sends *gray rami communicantes* to the anterior rami of each of the eight cervical nerves, roughly thus, 1–4 spring from the superior ganglion; 5 and 6 from the middle ganglion; 7 and 8 from the inferior ganglion.

A *cardiac branch* goes from each of the three ganglia to the cardiac plexus.

Vascular branches from the superior ganglion follow the internal and external carotid arteries and are distributed with their branches; branches from the middle ganglion are distributed with the inferior thyroid artery; and branches from the inferior ganglion are distributed with the vertebral artery and to the subclavian artery. A twig passes to the *carotid sinus.*

THE SUPERIOR GANGLION sends branches to everything in its neighborhood, i.e., to the first four *cervical nerves;* to the last four *cranial nerves* (the accessory excepted); to the *pharyngeal plexus,* joining there branches from nerves IX and X; and to the *cardiac plexus.* The *vascular branches* run thus: the superior thyroid artery conducts branches to the thyroid gland; the facial artery to the submandibular ganglion and so to the submandibular and sublingual salivary glands; the internal maxillary and middle meningeal arteries to the auriculo-temporal nerve, and so to the parotid gland; the internal carotid artery is accompanied by the *internal carotid nerve,* which sends twigs to the tympanum, to the petrosal nerves, and to the nerves in the cavernous sinus.

Paralysis of the Cervical Sympathetic results in Horner's syndrome, i.e., *ptosis* (drooping of the eyelid) and *enophthalmos* (recession of the eyeball) due to paralysis of the involuntary muscle in the lids and orbit; reduction of the intra-orbital pressure; *contraction of the pupil* due to the unopposed action of the oculomotor nerve; *vaso-dilatation* and *absence of sweating* on the affected side of the face.

THE MIDDLE AND INFERIOR GANGLIA send gray rami to the brachial plexus. These are numerous and variable in their course (*see p. 780*).

THE PHARYNX

Examination of the Detached Head and Pharynx from Behind.

The skull, pharynx, great vessels, last four cranial nerves, and sympathetic trunk (in short, all structures in front of the prevertebral fascia) are to be detached from the vertebral column. The Sterno-mastoid, Splenius Capitis, and Longissimus Capitis have already been severed from the mastoid process; the nuchal muscles must now be detached from the occipital squama; the Longus Capitis, Rectus Capitis Anterior, and Rectus Capitis Lateralis must be severed from the basi-occiput and jugular process; and ligaments uniting the occipital bone to the atlas and axis must be divided.

The foramen magnum and the condyles, skirting the anterior half of the foramen, are seen; and extending laterally from the posterior two-thirds of the condyles are the jugular processes. Behind each condyle there is a (posterior) condylar fossa which receives the margin of a condyle of the atlas during extension of the head and commonly has opening on to it a foramen for an emissary vein.

The structures on the now familiar "*posterior transverse line*" (*fig. 719*) that joins the anterior borders of the mastoids are to be defined.

They are (*fig. 720*): the styloid process with the facial nerve descending on its lateral side from the stylo-mastoid foramen, and the internal jugular vein descending on its medial side from the jugular foramen; also, the hypoglossal canal, separated from the jugular foramen by a bar of bone. Were it not for this bar the jugular and hypoglossal openings would be one. Because the glosso-pharyngeal, vagus, and accessory nerves emerge from the jugular foramen, and the hypoglossal nerve from the hypoglossal canal, it is evident that these four nerves are very close together and that the hypoglossal is the most medial. [Medial to these nerves is the

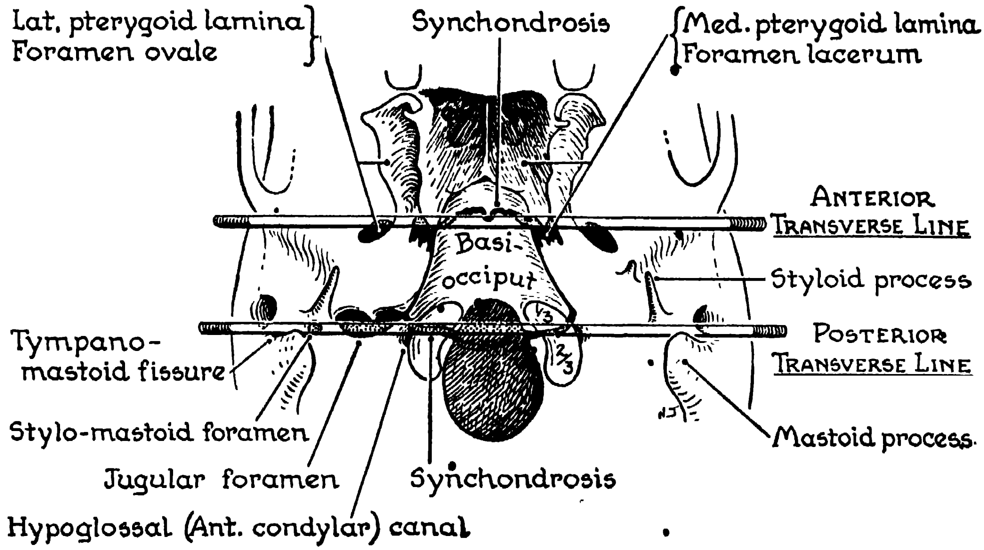


Fig. 719. The anterior and posterior transverse lines on the exterior of the base of the skull.

sympathetic trunk.] The four nerves and the trunk largely conceal the internal carotid artery. The posterior wall of the pharynx hangs from the basi-occiput, well in front of the foramen magnum, and has the great vessels and nerves lying postero-lateral to it. The pharynx is widest at the base of the skull and fibers of the sympathetic, traverses the carotid canal. Clearly, the carotid canal being intra-osseous (within the temporal bone) is anterior to the jugular foramen which is inter-osseous (between temporal and occipital bones). The following features are easily made out: the superior cervical ganglion of the sympathetic and

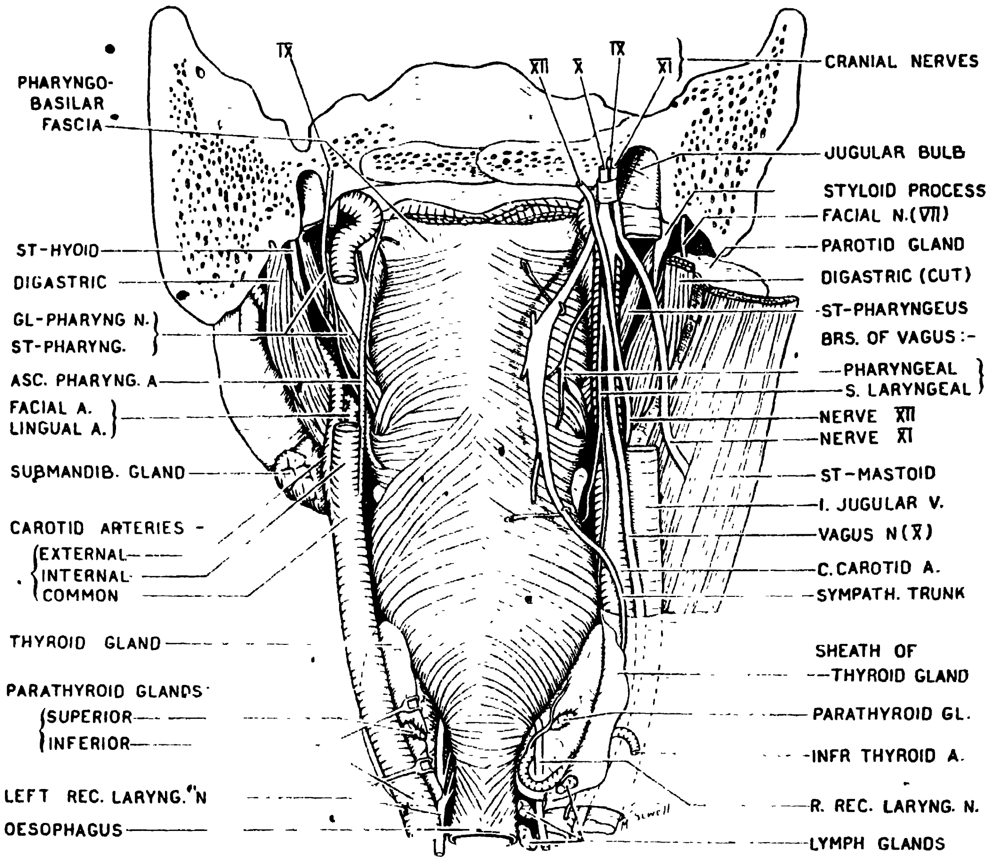


FIG. 720. The pharynx, last 4 cranial nerves, sympathetic trunk and great vessels—from behind. (The skull has been sectioned in "the posterior transverse line"—see fig. 719.)

narrowest where it tapers into the esophagus. There the thyroid gland is applied to its sides.

Of these structures at the base of the skull, the most posterior are the internal jugular vein and the XII nerve. Anterior to these are the IX, X, and XI nerves; and most anterior of all is the internal carotid artery which, with stout the inferior ganglion of nerve X, each from 1″ to 2″ long; nerve XII making a spiral behind the ganglion of nerve X; the cranial root of nerve XI joining nerve X beyond its ganglion; nerve IX and the pharyngeal branches of nerve X passing between the two carotid arteries; the pharyngeal branches of the sympathetic and the superior laryngeal br. of

nerve X passing medial to both carotids; the posterior belly of the Digastric and the styloid process with its 3 attached muscles lying between the pharynx and the Medial Pterygoid.

THE PROCEDURE IN THIS CHAPTER. It has been and still is the custom to study the pharynx and mouth and their relations by dissecting from the skin surface inwards, but more desirable knowledge is gained by working from the mucous surface outwards. Accordingly, in this chapter attention is directed to the work from the inside. Dissection, description, and comment are given concurrently. Almost no fat is met with, so, dissection amounts to little more than stripping off mucous membrane and defining the margins of muscles. This is easily done, provided - and only provided - the part is kept suitably moist, and the last few millimeters of the blade of the knife retain the sharpness of a razor.

The Pharynx is a fibro-muscular tube that extends from the base of the skull to the lower border of the cricoid cartilage where, at the level of vertebra C. 6, it is continuous with the oesophagus. At the base of the skull its postero-lateral angles reach almost to the carotid canals; here therefore it is 2 inches wide. At its junction with the oesophagus it is 1 inch wide and, because this is the narrowest part of the alimentary canal, a foreign body that passes the cricoid is not likely to be arrested farther on.

THE PHARYNGEAL WALL has four coats or tunics: (1) areolar, (2) muscular, (3) fibrous, and (4) mucous.

The Areolar Coat is continuous with the areolar coat of the Buccinator and is called the *buccopharyngeal fascia.* It contains the pharyngeal plexus of veins and of nerves. The *venous plexus* drains the pharynx including the soft palate and tonsil; it communicates with the pterygoid plexus; and it ends in the internal jugular vein near the angle of the jaw. The *nerve plexus* is formed by pharyngeal branches of the vagus, glosso-pharyngeal, and sympathetic nerves, which are motor, sensory, and vaso-motor respectively.

The Muscle Coat comprises five paired voluntary muscles, namely—

1. Superior }
2. Middle } Constrictors
3. Inferior }

which represent an outer "circular" coat,

4. Stylo- }
5. Palato- } pharyngeus

which represent an inner "longitudinal" coat.

The three constrictors are incomplete in front where the nose, mouth, and larynx open into the pharynx. Each is fan-shaped; and each is attached by its narrower end, or handle of the fan, to the side wall of the nasal, the oral, or the laryngeal cavity. Each widens posteriorly and joins its fellow in the median plane, and it partly envelops or overlaps externally the one above it, i.e., the Inferior overlaps the Middle, and the Middle overlaps the Superior. Each has a concave upper and lower border; the upper borders curve upwards in the median plane behind to, or nearly to, the pharyngeal tubercle on the basi-occiput, and from the tubercle a median fibrous raphe descends.

It is easiest to begin by placing the Middle Constrictor, thus:

The Middle Constrictor (fig. 721) arises from the angle between the greater and lesser cornua of the hyoid and from the lower end of the stylo-hyoid ligament. In order to expose the origin of this Constrictor, the Hyoglossus must be detached from the greater cornu and raised, together with the hypoglossal

nerve which runs across its superficial surface. The lingual artery, which runs across its deep surface, may be eased downwards.

The *Inferior Constrictor* arises from the oblique line on the thyroid cartilage behind the attachments of the Sterno-thyroid and Thyro-hyoid. It is unable to arise from the lateral aspect of the cricoid cartilage because this is monopolized by the Crico-thyroid; so, it springs from the fascial covering of the Crico-thyroid.

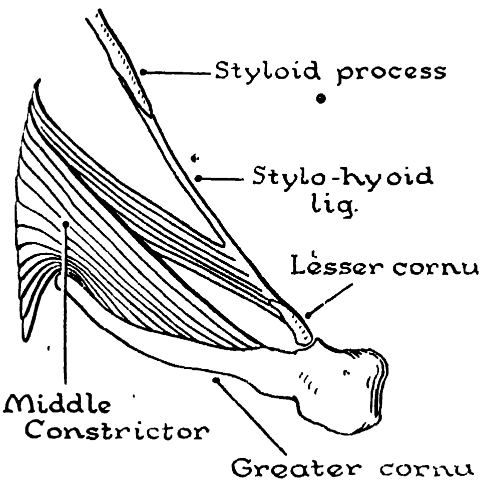


FIG. 721. The angular origin of the Middle Constrictor.

This thickens to form an arch that extends from the lower tubercle on the thyroid cartilage to the lower border of the cricoid cartilage. In thus creating an arcuate ligament out of fascia, the Inferior Constrictor follows the example set by the diaphragm (*fig. 302*).

The lowest fibers of the Inf. Constrictor, called the *Crico-pharyngeus*, being normally in a state of contraction, guard the oesophagus like a sphincter and prevent air from being sucked into it during respiration. (Negus; Raven.)

The *Crico-thyroid* is developmentally a *detached part of the Inf. Constrictor and* this accounts for the fact that its nerve, the external laryngeal, partly supplies and usually pierces the Inf. Constrictor on its way to the Crico-thyroid. The practical significance of this lies in the fact that when the thyroid gland and the superior thyroid vessels are pulled

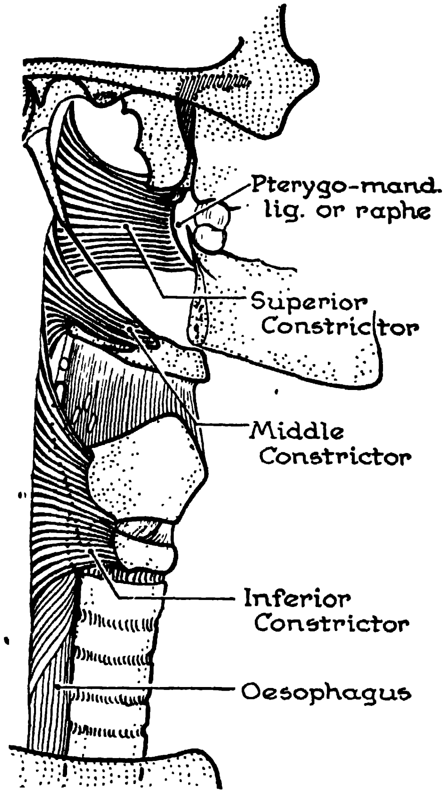


FIG. 722. The three Constrictors of the pharynx.

forwards during operations on the gland, the nerve tends to remain behind.

The *Superior Constrictor* arises from the pterygo-mandibular lig. or raphé and from the bony point at each end of the ligament, i.e., the lower end of the medial pterygoid plate and the mandible behind the 3rd molar tooth. Some fibers spring from the tongue.

The longitudinal or inner muscle coat *formed by the Stylo-pharyngeus and*

Palato-pharyngeus will be examined from the interior of the pharynx (*p. 733*).

The Fibrous Coat, called the *pharyngo-basilar fascia*, corresponds to a tunica submucosa. It is especially strong above, where it serves to anchor the pharynx to the posterior border of the medial pterygoid plate, to the basi-occipital, and to the petrous bone. At the upper concave border of the Superior Constrictor a semilunar portion of the fascia (sinus of Morgagni) is visible from without (*fig. 720*).

The Mucous Coat is described with the *interior of the pharynx.*

Structures Crossing the Borders of the Constrictors. Certain nerves, vessels, muscles, and the pharyngo-tympanic tube pass through the four angular gaps that occur above and below the handle-like origins of the Constrictors: (A) The *recurrent nerve* and its companion artery, the *inferior laryngeal a*, pass into the pharynx through the gap between the oesophagus and the I. Constrictor. The nerve is closely applied to the back of the crico-thyroid joint and it may readily be involved in inflammation of the joint. Before traversing the gap, the nerve and artery send twigs to the oesophagus,

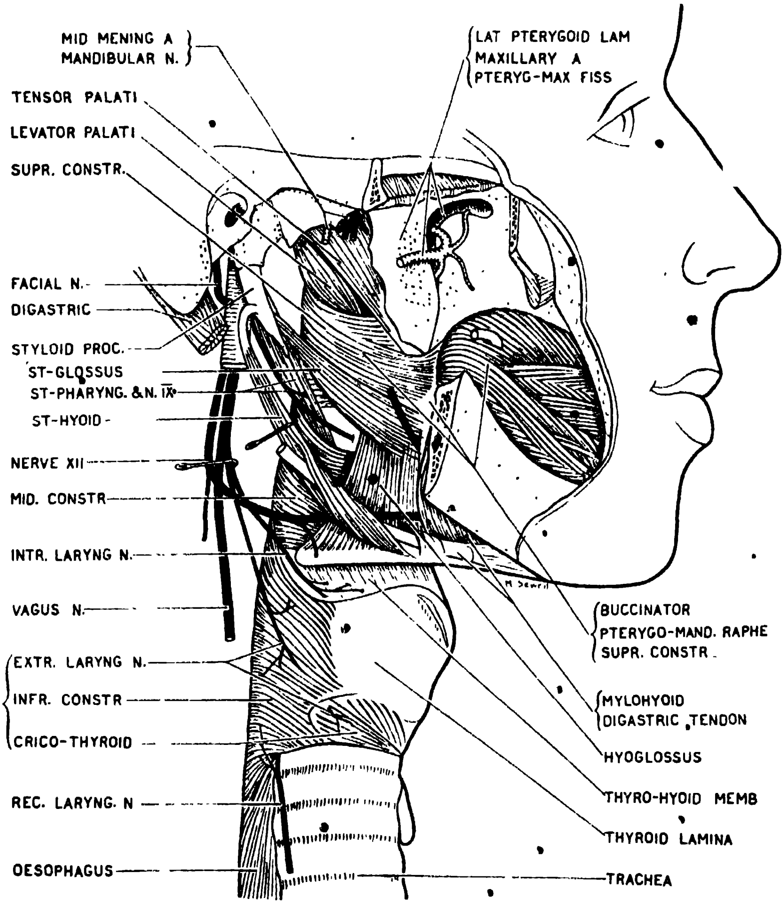


FIG. 723. The lateral aspect of the pharynx.

trachea, and I. Constrictor. The nerve is usually in two bundles. (B) *The internal laryngeal nerve* and *superior laryngeal vessels* pierce the thyro-hyoid membrane under cover of the Thyrohyoid in the gap between the I. and M. Constrictors. (C) *The Stylo-pharyngeus* passes through the gap between the M. and S. Constrictors, amalgamates with the Palato-pharyngeus, and gains attachment to the greater horn of the hyoid and posterior border of the thyroid cartilage. This attachment will be seen if the I. Constrictor is detached from the oblique line and thrown backwards. *The glosso-pharyngeal nerve*, after making a partial spiral around the Stylo-pharyngeus, passes through the same gap. The Stylo-glossus and the lingual nerve pass forwards in the same interval but they enter the mouth. (D) *The pharyngo-tympanic* or *auditory tube*, the *Levator Palati*, and the *ascending palatine artery* pass through the gap between the S Constrictor and the base of the skull.

The Interior of the Pharynx. INSPECTION (*fig. 724*).

With scissors or scalpel, slit the posterior pharyngeal wall right up to the base of the skull, and view the pharynx from within

Opening into the pharynx anteriorly are orifices leading from the cavities of the nose, mouth, and larynx. Accordingly, the pharynx is divided into 3 parts: the *naso-pharynx*, *oral pharynx*, and *laryngeal pharynx*. The soft palate, ending in the uvula, hangs down and separates the naso-pharynx above from the oral pharynx below.

The Naso-pharynx lies above the soft palate and behind the nasal cavities. It is, in fact, the backward extension of the nasal cavities and it cannot be shut off from them. Therein it differs from the oral pharynx which can be shut off from the mouth, and from the laryngeal pharynx which can be shut off from the larynx. In front, are two oblong rigid bony orifices, the *posterior apertures* (*choanae*) *of the nose* described on page 704. On looking through these apertures the posterior ends of the middle and inferior conchae are seen On the side wall of the pharynx, half-an-inch behind the inferior concha, is the orifice of the *pharyngo-tympanic tube* (the auditory tube of Eustachius). Its upper and posterior lips are prominent and cartilaginous. A fold of mucous membrane, the *salpingo-pharyngeal fold*, overlying a muscle of the same name, descends from the postero-inferior part of the orifice and gives it the appearance of a hook. Behind the orifice of the tube there is a vertical cleft, the *pharyngeal recess*, which extends under the petrous bone almost to the carotid canal; so, here the pharynx is two inches wide. The *roof*, formed by basi-occipital and petrous bones, is rounded off into the posterior wall which lies in front of the atlas and axis but with prevertebral fascia and prevertebral muscles intervening On the roof there is some lymphoid tissue, the *naso-pharyngeal tonsil*, which when overgrown is known as "adenoids" (*fig. 745*). This tissue extends into the pharyngeal recess behind the pharyngo-tympanic tube and. when hypertrophied, it can, by compressing the tube, interfere with access of air to the middle ear with resulting deafness.

The Oral Pharynx is placed below the soft palate and behind the mouth and tongue. From the soft palate two folds of mucous membrane arch downwards on each side. The anterior fold, the *palato-glossal arch*, overlies a muscle of the same name and descends to the junction of the anterior $\frac{2}{3}$ and posterior $\frac{1}{3}$ of the tongue. It lies at the dividing line between mouth

and pharynx. The posterior fold, the *palato-pharyngeal arch*, also overlying a muscle of the same name, arches downwards to be lost on the side wall of the pharynx. On each side between the two palatine arches lies the tonsil (palatine tonsil).

tenoideus which unites these cartilages; on each side, by the *ary-epiglottic fold* which extends from epiglottis to arytenoid. Slightly in front of the apex of the arytenoid cartilage, which is surmounted by the *corniculate cartilage*, is the rounded end of the *cuneiform car-*

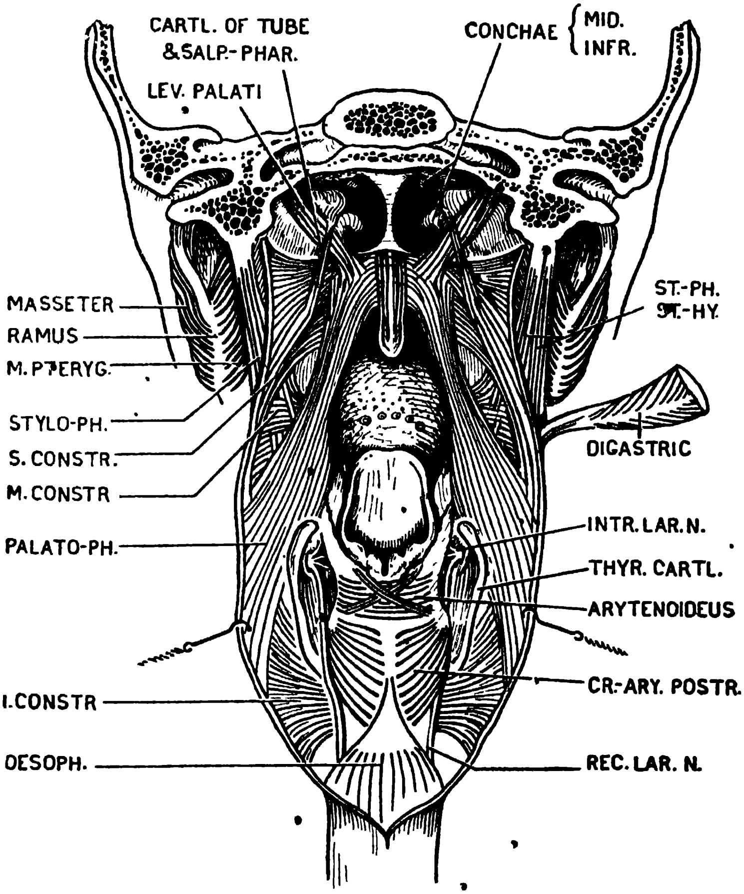


FIG. 724. The muscles of the pharynx, from within.

The Laryngeal Pharynx lies behind and around the freely projecting upper end of the larynx. The *inlet of the larynx* is oval and obliquely placed. In front it is formed by the free, curved upper end of the *epiglottis*; behind, by the mucous membrane clothing the apices of the *arytenoid cartilages* and the *Arytilage*. Three folds of mucous membrane leave the epiglottis: one, the *glosso-epiglottic fold*, connects it in the median plane with the back of the tongue; one on each side, the *pharyngo-epiglottic fold*, connects it with the pharyngeal wall. Between these three folds are two finger-tip depressions, the *valleculae*. Behind

the pharyngo-epiglottic fold on each side there is a space, the *piriform fossa,* which is bounded by the thyroid cartilage and thyrohyoid membrane laterally and by the wall of the larynx medially. On the posterior wall of the pharynx numerous *lymphoid follicles* are scattered. They may become enlarged.

Exposure of the Internal and Recurrent Laryngeal Nerves. These two nerves, being submucous, are readily exposed. The *internal laryngeal nerve,* having pierced the thyrohyoid membrane, runs transversely in a fold across the front of the piriform fossa; it is a sensory nerve. The *recurrent laryngeal nerve* runs vertically applied to the back of the crico-thyroid joint. It is a mixed nerve which supplies all the muscles of the larynx except the Crico-thyroid. (*See pp. 765-766.*)

The Bisected Head. Orientation of the Bisected Head (*figs. 725, 746*).

Having sawn through the skull on the right side of the median sagittal plane, and thereby divided it into right and left halves, orient the section as though it were in the erect posture Recall that in the quadruped the *foramen magnum* looks backwards, in the ape and in primitive (Neanderthal) man downwards with a slight inclination backwards and in modern man downwards with a slight inclination forwards. Clean the margin of the foramen and so hold the specimen that the antero-median point of the foramen (basion) is from one to five mm. higher than the postero-median point (opisthion).

When so oriented, the hard palate is seen to be almost horizontal and its plane, if produced backwards, usually strikes the vertebral column just below the foramen magnum.

Exploration of the Spheno-palatine Foramen. Push the end of a seeker through the mucous membrane and lateral wall of the nasal cavity at a point just above the middle concha and a quarter of an inch in front of its posterior end. This point is flush with the under surface of the body of the sphenoid bone. The hole entered is called the *spheno-palatine foramen* because the sphenoid bounds it above and the palatine bone bounds it in front, below, and behind. The chief vessels and nerves of the nasal cavity pass through this foramen; so, in a sense it is the "porta" or door of the nasal cavity (*figs. 743, 728*).

Substitute a long straight needle for the seeker and force it horizontally through the foramen; and, for purposes of orientation, observe that it traverses the pterygo-palatine and infratemporal fossae and strikes the zygomatic arch far forwards.

Recall that before the palate appeared the nasal and oral cavities were one, the *stomodaeum,* and that the greater part of its side wall developed in the *maxillary process,* the nerve supply of which was the maxillary nerve (V^2). Subsequently this nerve becomes the nerve of the palate also.

When studying the infratemporal fossa, the third part of the (internal) maxillary artery was seen to disappear into the pterygo-palatine fossa. There it meets the maxillary nerve and breaks up into branches which accompany the branches of the maxillary nerve through various foramina including the spheno-palatine and greater and lesser palatine.

The Under Surface of the Palate. The anterior two-thirds of the palate is called the *hard palate* because its framework is the bony palate; the posterior third is called the *soft palate* because it is composed of muscles and soft tissues. At its anterior part are several rudimentary ridges. In most mammals these are numerous and prominent and against them the tongue triturates food. Pin-point orifices of the *ducts of mucous glands* are dotted over the hard palate, giving it

an orange-skin appearance, and they are abundant over the soft palate.

Piercing the bony palate medial to the third molar tooth is the *greater palatine foramen.* It lies almost vertically below the spheno-palatine foramen. The greater palatine vessels and nerve emerge from this foramen and run forwards in two

should be made to penetrate the mucous membrane of the palate abreast of the second molar tooth and it should be pushed upwards and backwards until its tip slips over the rounded anterior margin of the foramen.

There is, of course, no muscle under the hard palate——it could there have no

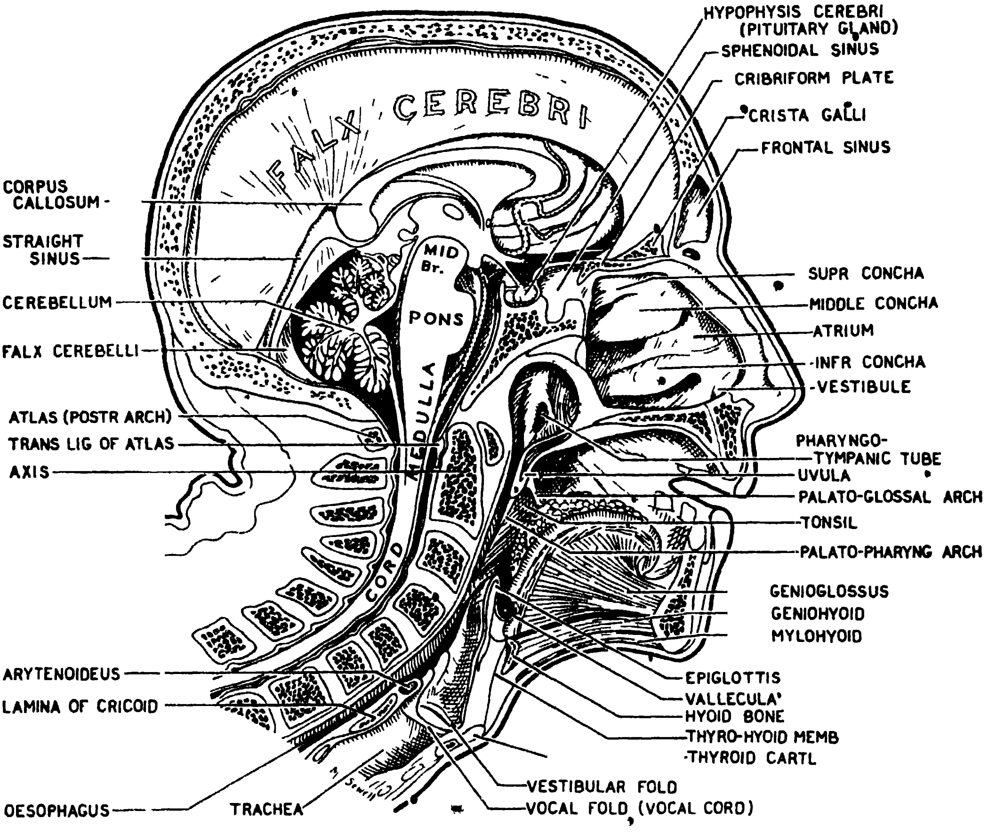


FIG. 725. The bisected head—left side.

grooves, separated by a sharp crest, on the under aspect of the bony palate near the alveolar margin. It follows on general - principles that the anterior margin of the greater palatine foramen must be smooth and rounded (cf. infra-orbital, mental, anterior sacral foramina, and medullary foramina of long bones). Therefore, to find the foramen a seeker

function. The brown tissue seen there is a carpet of racemose mucous glands, which becomes much thicker under the soft palate. The periosteum adheres more intimately to the mucous membrane than to the bone; hence, the two are referred to as *muco-periosteum.*

With the aid of the handle and point of the knife, ease the muco-periosteum off the palate.

First make a transverse cut through the thickness of the tissues of the palate, beginning just behind the point at which the seeker was inserted into the greater palatine foramen and ending at the sawn edge in the middle line. Be sure to keep the cut $\frac{1}{4}''$ in front of the posterior sharp border of the hard palate, thereby avoiding injury to the palatine aponeurosis which is attached to, and is continuous with, this sharp border. Now, with the rounded handle of the knife, ease an anterior flap of muco-periosteum off the hard palate as far laterally as the alveolar margin, and free the vessels and nerve issuing from the greater palatine foramen and passing forwards. If, in dealing with the soft palate, you begin at

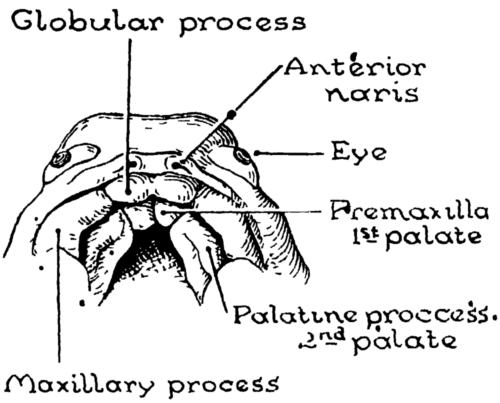


FIG. 726 The palate develops from 3 shelves: anterior, right, and left

the lateral end of the transverse cut and ease the muco-periosteum from off the remaining $\frac{1}{4}''$ of the hard palate, you will be conducted to a plane beneath the palatine aponeurosis and so will avoid injuring it, as you turn down a posterior flap. On encountering muscle in the soft palate, you will require the assistance of the point of the knife.

The *palatine aponeurosis* in which the bony palate ends is the pliable basis of the soft palate; it may be regarded as its unossified skeleton.

Piercing the bony palate behind the incisor teeth is the *incisive canal.* This canal runs between two developmental areas (1) the *primary palate* which developed from the globular (fronto-nasal) process and which is part of the premaxilla or bone bearing the incisor teeth (*fig. 726*); and (2) the *secondary palate* which developed from the right and left maxillary processes. A process of the nasal septum (the vomer) descends into the incisive canal dividing it into right and left sides. Through each side a branch of the *greater palatine artery* ascends to anastomose on the nasal septum with the long spheno-palatine (naso-palatine) artery, and the *long spheno-palatine nerves* descend through the hinder part of the canal to the under surface of the premaxilla. This canal is patent in lower animals (the cow) and is known as the incisive duct. It apparently allows the odors of food in the mouth to ascend to the nasal cavities, there to stimulate the naso-vomerine *organ of Jacobson* —an inverted tube of mucous membrane stiffened by a scroll of cartilage which projects from each side of the septum a little above the opening of the duct and receives a branch of the olfactory nerve. The organ is present in man at the time of birth.

The thickness of the *soft palate* is due to glands and to a smaller extent to muscles; its strength depends upon the aponeurosis which occupies its anterior half. A stitch will tear through muscle and gland; so, the palatine aponeurosis should be included in the grip of a stitch that is intended to hold.

Exploration of the Greater Palatine Canal. Situated $\frac{1}{3}''$ to $\frac{1}{2}''$ behind the posterior end of the inferior nasal concha is the orifice of the pharyngo-tympanic tube. This orifice rests against the posterior edge of the medial pterygoid lamina which, therefore, is also $\frac{1}{3}''$ to $\frac{1}{2}''$ behind the inferior concha. The posterior edge of this lamina is taken as the *boundary line* between the nasal cavity and the naso-pharynx.

Incise the muco-periosteum of the nose along the line joining the spheno-palatine and the greater palatine foramina. The fleshy tips of the middle and inferior conchae will be severed because they extend backwards on to the vertical plate of the palatine bone, and the knife will be arrested below by the horizontal part of the palatine bone. Then, with the handle of the knife strip back the mucoperiosteum for the requisite third of an inch, in order that the entire medial aspect of the medial pterygoid lamina may be exposed and its posterior border, which gives attachment to the pharyngo-basilar fascia, defined.

Pass a long needle into the greater palatine foramen and upwards through the greater palatine canal and pterygopalatine fossa to the level of the spheno-palatine foramen and leave it in situ. Then, with a strong probe proceed to break down the delicate intervening portion of the lateral wall of the nose formed by the *vertical plate of the palatine bone*. This exposes the greater palatine nerve and artery.

The nerve is to be followed to the *spheno-palatine ganglion* which hangs from the maxillary nerve (*p. 750*); the artery, being a branch of the maxillary artery, naturally lies lateral to the nerve.

Between the greater palatine foramen and the hamulus is the *tubercle* (pyramidal process) of the palatine bone. It is pierced by two small foramina, the *lesser palatine foramina*, which transmit the lesser palatine vessels and nerves to the neighborhood of the soft palate and tonsil.

The Palatine Tonsil (*figs. 727, 729*). The tonsil resembles an ovary in shape and size. It is embedded in the side wall of the pharynx in the triangular interval between the palato-glossal and palato-pharyngeal arches and the posterior third of the tongue. An upper and a lower fold of mucous membrane (plica semilunaris and plica triangularis) may extend from the palato-glossal arch backwards over its anterior part forming an upper and a lower pocket.

Proceed to remove the tonsil. Begin by incising the mucous membrane along the palato-glossal arch, and then with the point and handle of the knife free the upper part of the anterior border of the tonsil.

This is easily done because the rounded lateral aspect of the gland has a *fibrous capsule* which is separated from the

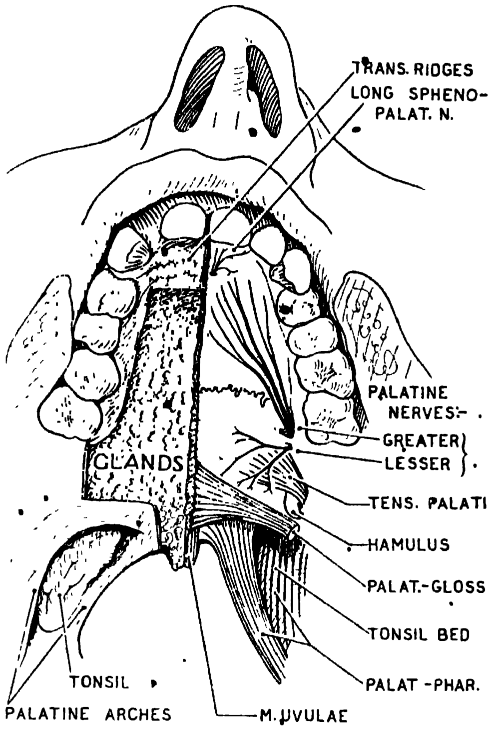


FIG. 727. Dissection of the palate and palatine arches.

pharyngeal wall by a layer of *loose areolar tissue* in which free dissection is readily made.

If, as a result of tonsillitis, the areolar space is in part obliterated and dissection difficult, prefer damaging the tonsil to damaging the pharyngeal wall. After setting free the anterior part of the tonsil, shell out the *upper pole* which extends upwards into the soft palate beyond the arches, and is there buried. Then free the posterior border. Working always in the areolar space, detach the rest of the gland (i.e., lower pole and lower part of

anterior border where the gland is most adherent).

The upper pole of the tonsil is, then, buried in the soft palate. The lower pole is continuous with the lymphoid follicles on the dorsum of the tongue, collectively called the *lingual tonsil*; this pole is not visible in life unless the tongue is depressed. A prominent anterior pillar may largely conceal even an enlarged tonsil.

The lower part of the tonsil is moored to the tongue by a fibrous band and by some muscle fibers which help to prevent it from being swallowed. These and the vessels and nerves, which enter near the lower pole, must be severed during the removal of the tonsil.

When the tonsil has been enucleated, make a section through it and observe the white test-tube-like *crypts* that extend from its free surface almost to the very capsule. Tonsils are the only lymphoid organs covered with *stratified squamous epithelium*, and by this fact they can be identified microscopically. The epithelium lines the crypts also; and surrounding the crypts are spherical germinal centers from which cells wander through the walls of the crypts into their lumina.

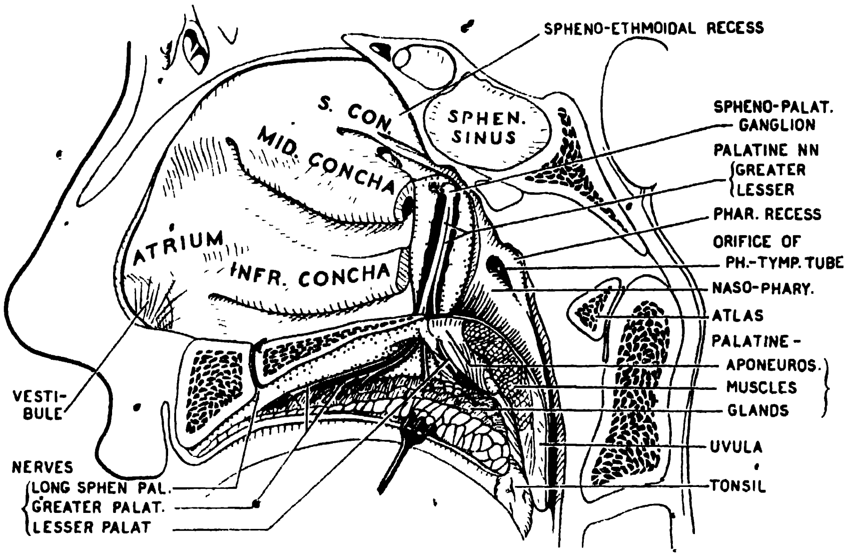


FIG. 728. Dissection of under surface of palate. Exploration of greater palatine canal.

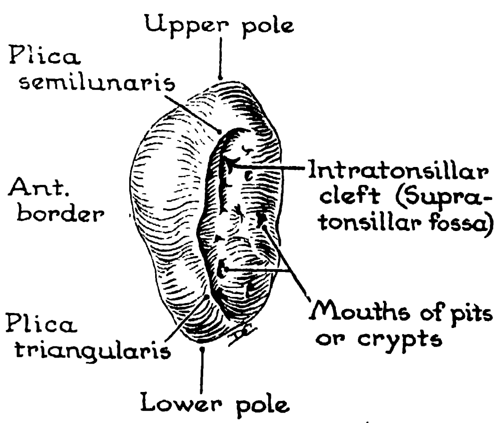


FIG. 729. The tonsil, medial aspect.

The Tonsil Bed. Lateral to the loose areolar tissue surrounding the fibrous capsule of the tonsil there are three thin sheets—one fibrous and two fleshy—which constitute the tonsil bed. From

within outwards they are (1) the *pharyngo-basilar fascia* (now lying exposed) which forms a complete filmy sheet, and (2) the *Palato-pharyngeus* and (3) the *Superior Constrictor* both of which are deficient below (*fig. 730*). A large vein, the *paratonsillar vein*, descending from the soft palate and receiving tributaries from the tonsil, pierces the lower part of the tonsil bed to join the pharyngeal plexus; it is not likely to be seen, unless engorged.

Two structures passing to the tongue, (1) the *Stylo-glossus* and (2) the *glossopharyngeal nerve*, form immediate lateral relations of the lower third of the tonsil bed.

They are to be exposed and cleaned by removing the thin fascial sheath which alone covers them here, the muscle sheets having faded off into delicate arched borders.

The Styloglossus is a broad thick muscle band that commonly stands out in relief as it passes downwards, medially, and forwards to the horizontal part of the tongue (i.e., the anterior $\frac{2}{3}$). *The Glossopharyngeal Nerve* is larger than the internal laryngeal nerve and is placed far back; on appearing from under cover of the lower arched borders of the muscle sheets, it passes downwards, medially, and forwards to spread out submucously over the vertical part of the tongue (i.e., the posterior $\frac{1}{3}$). Look for it immediately lateral to the palato-pharyngeal arch, two-thirds of the way down the tonsil bed.

The posterior belly of the Digastric and the submandibular gland with the facial artery arching over them are lateral relations of the lowest part of the bed—they should be exposed now. Further laterally are the Medial Pterygoid and the angle of the jaw—but these will be seen later.

Vessels and Nerves of the tonsil. They are: the *tonsillar branch of the facial artery;* veins which pass through the tonsil bed to the *pharyngeal plexus* of veins and to the common facial vein; lymph vessels, which pass through the bed to a *deep cervical gland* below the angle of the jaw; and nerve twigs from *nerve IX*. The *lesser palatine nerves* (N.V^2) also supply it.

The *bed* receives arterial twigs from the *tonsillar* and *ascending palatine branches* of the facial a., the *dorsales linguae aa.*, *ascending pharyngeal a.*, and *lesser palatine aa.* In the event of haemorrhage, they are controlled by tying the external carotid a. at its origin.

The Hyoid Bone. No muscle crosses the hyoid bone; so, it is subcutaneous in the neck and submucous in the pharynx. This makes it an important landmark (*figs. 725, 795*).

Pull backwards the epiglottis and incise the mucous membrane along the body and greater horn of the hyoid down to the bone. The incision will pass between the epiglottis and the tongue, across the valleculae and the glosso-epiglottic and pharyngo-epiglottic folds. To get free exposure carry the incision along the greater horn to its tip and beyond this to the median plane; then strip the mucous membrane from the pharyngeal wall upwards over an area extending from the level of the back of the tongue below to the level of the soft palate above. Find the lesser horn, which till after middle life is cartilaginous, and carry the point of the knife upwards and backwards along the anterior free edge of the stylohyoid ligament towards the styloid process of the temporal bone, but stop at the curved lower border of the Palato-pharyngeus.

These 3 structures—the styloid process, the stylo-hyoid ligament, and the lesser horn—are derivatives of the cartilage of the 2nd visceral arch. Since the M. Constrictor takes origin in the angle between the two horns of the hyoid and

the lower end of the stylo-hyoid ligament, it also is submucous at its origin. Being fan-shaped, its borders curve up and down; and along its upper border runs the IX nerve. A few deep fibers of the Hyoglossus pass from the cartilaginous lesser horn to the tongue—hence called the Chondroglossus—and when removed, the lingual artery and the Hyoglossus are in view. The Hyoglossus arises from the whole length of the greater horn. It is crossed on its medial surface by the lingual artery and on its lateral surface by the hypoglossal nerve. Though the nerve should not be disturbed just now, its thick trunk should be identified at the posterior border of the Hyoglossus where it is superficial to the lingual artery.

The Palato-glossus and Palato-pharyngeus. On freeing the mucous membrane from the palato-glossal arch, the *Palato-glossus* is displayed as a small bundle of fibers that extends from the soft palate above, where its fibers mingle with those of the opposite side, to the tongue below, where the fibers enter as transverse fibers. A more or less circular sphincter is thus formed which guards the entrance to the pharynx, called the *oro-pharyngeal isthmus* (isthmus of the fauces).

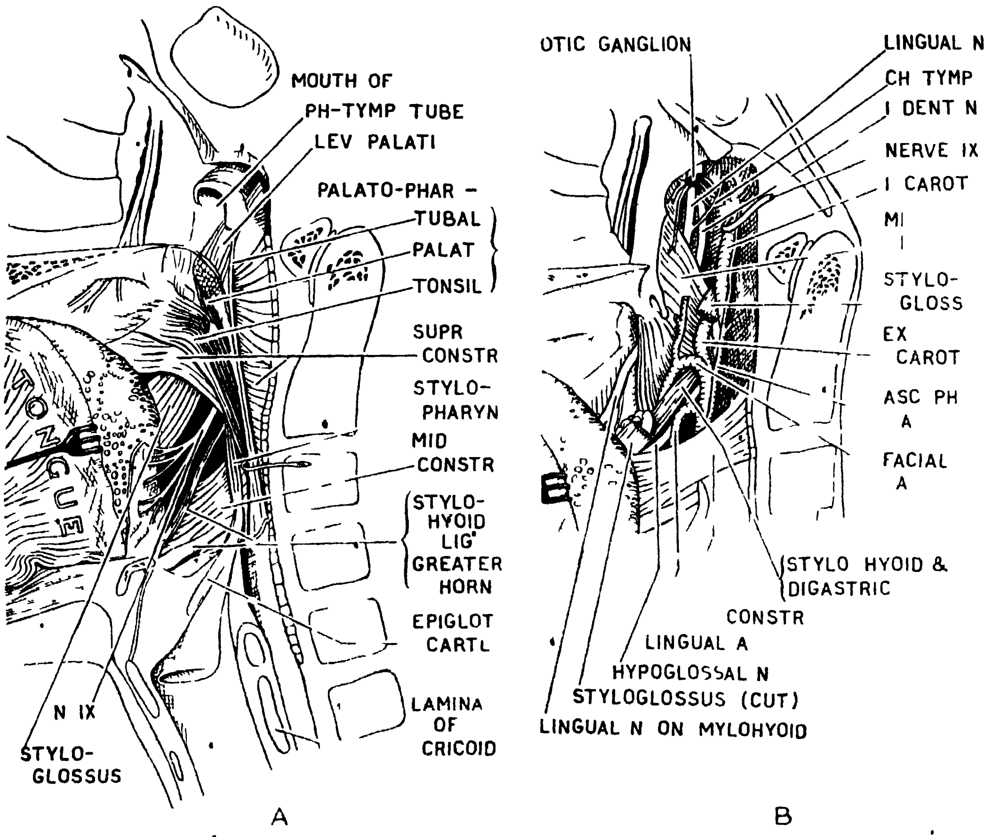


FIG. 730. Two stages in the dissection of the side wall of the pharynx from within, showing particularly the relations of the tonsil bed. (By Dr. B. L. Guyatt.)

Strip the mucous membrane from the upper surface of the soft palate and from the whole

naso-pharynx up to the level of the pharyngo-tympanic tube, thereby exposing the Palato-pharyngeus.

The *Palato-pharyngeus* is to be regarded as a delaminated portion or detached inner sheet of the S. Constrictor which has been called into being with the appearance of the palate.

A palate is peculiar to mammals including man. Mammals require lips with which to grasp the nipple of the mammary gland—otherwise they could not suck. Equally, they require an extensive hard and soft palate with which to shut off the nasal cavities and naso-pharynx when sucking—otherwise air would be inspired with greater ease than milk could be imbibed, as happens in children born with cleft palates. With the appearance of the palate new muscles are not called into being but pre-existing ones are modified. These may be derived either from the immediate neighborhood or from a distance. The muscles may, so to speak, be *native* or *immigrant*. All the muscles of the soft palate, save one, are native. They belong to the same group as the S. Constrictor and have the same nerve supply, the accessory nerve via the pharyngeal plexus. The *Tensor Palati* is the immigrant; its nerve comes from the mandibular nerve (V^3) via the otic ganglion.

Traced upwards the *Palato-pharyngeus* is found to separate into three distinct parts—tubal, palatine, and tonsillar. Its *tubal fibers*, the Salpingo-pharyngeus, form a slender bundle that ascends in the salpingo-pharyngeal fold to the lower edge of the cartilage of the pharyngo-tympanic (auditory) tube. Its *palatine fibers* spread out in the posterior two-thirds of the soft palate. Its *tonsillar fibers* spread out within the tonsil bed.

Traced downwards the Palato-pharyngeus spreads out so as to form an almost complete inner sheet of muscle in the lower parts of the pharynx; some fibers pass to the posterior border of the thyroid cartilage and some to the hyoid.

The posterior edge of this muscle is easily identified because its fibers run nearly vertically whereas those of the Constrictor lie outside it and take a more horizontal course. Define and raise the posterior edge of the Palato-pharyngeus; divide it transversely at the level of the hyoid bone and dissect its severed ends up and down.

A little care is needed to avoid injuring the rounded *Stylo - pharyngeus*, which passes through the hinder part of the gap between S. and M. Constrictors and blends with the Palato-pharyngeus.

Detach the tubal fibers from the pharyngo-tympanic tube; trace the palatal fibers into the palate; and if feasible, separate the tonsillar sheet of fibers from the more superficial S. Constrictor and trace it forwards to the thread-like pterygo-mandibular ligament from which it takes origin. Having freed the muscle, discard it.

The origin of the *Superior Constrictor* is now unveiled. It is practically co-extensive with the tonsillar part of the Palato-pharyngeus. It arises from the pterygo-mandibular ligament (raphe), which unites it to the Buccinator, and from the bony parts at both ends of the ligament, namely, the hamulus of the pterygoid plate above, and the mandible behind the third molar tooth below; and fibers join the tongue.

The Side Wall of the Naso-pharynx

The following have been observed:

(1) The orifice of the pharyngo-tympanic tube, ⅓″ to ½″ behind the inferior concha,

(2) the pharyngeal recess, behind the orifice of the tube, and

(3) the naso-pharyngeal tonsil, on the posterior wall of the pharynx and extending into the recess.

The following are now to be observed:

(1) The upper border of the S Constrictor,
(2) the pharyngo-basilar fascia,
(3) the Levator Palati and Tensor Palati, and
(4) the ascending palatine artery.

All remaining mucous membrane is now to be removed from the naso-pharynx. This is readily done unless adhesions, resulting from adenoids, have formed behind the tube.

The Upper Concave Border of the Superior Constrictor. The posterior nasal aperture is bounded by bone; so, it cannot be closed. The Superior Constrictor makes no attempt to close it; in fact, it is deficient here. Its upper border curves from the hamulus and from the lowest limit of the free border of the medial pterygoid plate to the pharyngeal tubercle on the basi-occipital.

The Pharyngo-basilar Fascia, which represents a submucous coat, closes the gap between the upper border of the S. Constrictor, the medial pterygoid plate, and the base of the skull. It suspends the pharynx from the base of the skull and, accordingly, it is stronger there than lower down. The *tube, Levator Palati,* and the *ascending palatine artery* pass through the gap.

The Pharyngo-tympanic Tube (Auditory tube of Eustachius) is developmentally continuous with the tympanum and tympanic or mastoid antrum; so, its direction is backwards, laterally, and slightly upwards towards the mastoid process (*fig 758*). A bristle passed along it in this direction for 1½ inches appears through the anterior wall of the tympanum. Fluid syringed through the nose is in danger of entering the forwardly directed mouth of the tube and of travelling to the tympanum. This, indeed, is the route by which infections spread from the throat to the middle ear.

The medial inch of the tube is *cartilaginous*; the lateral half inch is *bony.* The narrowest part, called the *isthmus,* is where bone and cartilage meet medial to the spine of the sphenoid. It is 2 to 3 mm. high and 1.0 to 1.5 mm. wide.

The cartilaginous part occupies the fissure between the petrous bone and the greater wing of the sphenoid. The cartilage of the tube is curved like an inverted J, but it forms only the upper and medial walls of the tube; the lower and lateral walls are membranous. Except at the funnel-shaped *mouth* or *pharyngeal orifice,* the membranous lateral wall is applied to the cartilaginous medial wall, so that the lumen is closed to form a vertical slit. The mouth is firmly bound to the posterior border of the medial pterygoid plate and there rests on a projecting spine. The Levator Palati runs submucously below the mouth of the tube, raising its floor.

Function. When relaxed, the slit-like lumen of this air duct is closed, but during the act of swallowing and also of yawning and of sneezing, though apparently by no other natural means, it is opened reflexly through the action of the Tensor Palati (Rich). As a result, the atmospheric pressure on each side of the ear drum is maintained in equilibrium. While awake, one swallows once every minute; while asleep, once every five minutes (Graves and Edwards). Hence, while ascending and descending in an aeroplane be awake.

Nerve Supply. Via its tympanic branch the glossopharyngeal nerve (IX) is sensory to the tube, and via its pharyngeal branch it is sensory to the mouth of the tube. Perhaps the pharyngeal branch of the maxillary nerve (V^2) sometimes supplies the mouth.

The Levator Palati and Tensor Palati arise close together from the base of the skull, one on each side of the tube. Both muscles descend to the soft palate, the Levator to elevate and pull backwards the posterior part, the Tensor to depress and render tense the anterior part, and also to open the tube.

The Levator Palati is as stout as a lead pencil. It arises from the under surface of the petrous bone in front of the carotid canal. It runs beneath the whole length of the membranous floor of the tube and, therefore, accompanies it downwards, forwards, and medially and across the upper border of the S. Constrictor. Below the mouth of the tube it enters the upper surface of the soft palate and there spreads out to join its fellow and the palatine aponeurosis. The ascending palatine branch of the facial artery accompanies it into the soft palate.

Pass the handle of the knife between the Levator and the tube, and separate them. Free the tube from the pterygoid plate and cut it short. Remove the pharyngo-basilar fascia and expose the origin of the Levator. Divide the Levator. Pick away some fat and expose the Tensor.

The Tensor Palati is thin and fan-shaped. Its origin extends from the spine of the sphenoid to the scaphoid fossa at the root of the medial pterygoid plate. It also arises from the whole length of the membranous lateral wall of the tube. It descends lateral to the S. Constrictor and medial pterygoid plate to below the level of the hard palate. Then, after piercing the attachment of the Buccinator to the pterygo-mandibular lig., it utilises the hamulus as a pulley and takes a recurrent course to its insertion into the palatine aponeurosis.

The Tensor must on principle be tendinous where it turns around the pulley; and on principle there must be a bursa to facilitate the play of the tendon on the pulley. These conditions are similar to those encountered by the Obliquus Oculi Superior at its pulley.

The hamulus, or hook-like lower end of the medial pterygoid plate is, then, a pulley around which the Tensor Palati takes a recurrent course. It is situated about half an inch behind the greater palatine foramen. It can be palpated in life from the mouth by pressing upwards immediately postero-medial to the maxillary tuberosity. This point is a little in front of the palato-glossal arch.

Trace the Tensor throughout.

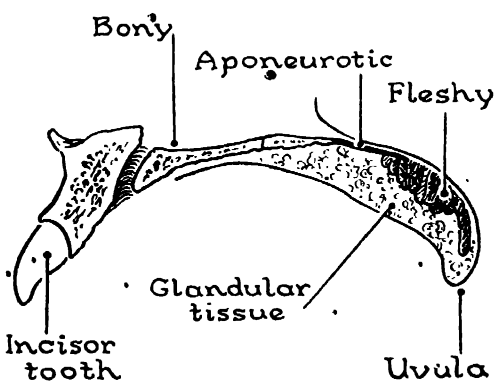


FIG. 731. The palate on sagittal section.

Review of the Soft Palate. It is a general principle that free surfaces that are subjected to friction, pressure, or other rough treatment are lined with *stratified squamous epithelium.* The under aspect of the soft palate comes into contact with food, and the posterior part of its upper surface strikes the posterior pharyngeal wall during the act of swallowing; so, these parts are lined with stratified squamous epithelium. The remainder of its upper aspect is lined with *ciliated epithelium,* as is most of the nasal cavity and naso-pharynx.

A thick carpet of racemose mucous *glands* covers the under surface of the soft palate (*fig. 731*).

It is important to note that the anterior one-third of the soft palate is *aponeurotic* and the posterior two-thirds *fleshy*; but it is not important to know the detailed arrangement of the fleshy fibers by layers. There is, then, a *bony palate*, an *aponeurotic palate*, and a *fleshy palate*. The aponeurosis is continuous in front with the sharp, posterior border of the hard palate, and laterally with the pharyngo-basilar fascia. In essence, it is the aponeuroses of the two tensor muscles, though the other palatine muscles gain partial attachment to it.

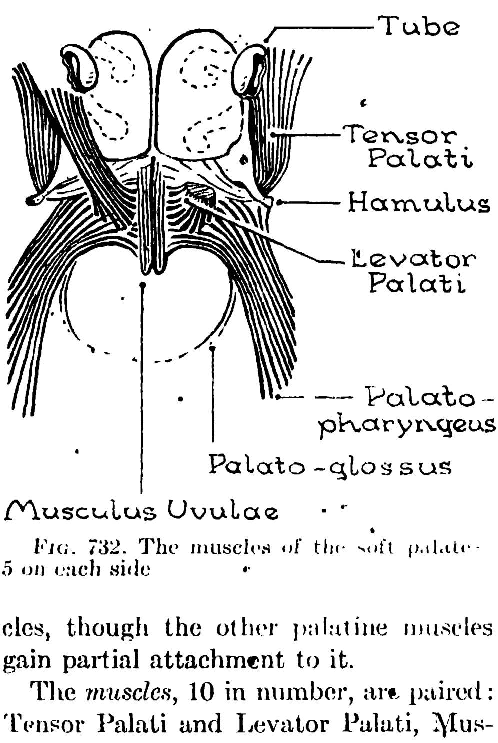


FIG. 732. The muscles of the soft palate—5 on each side

The *muscles*, 10 in number, are paired: Tensor Palati and Levator Palati, Musculus Uvulae, Palato-glossus and Palato-pharyngeus.

The two Musculi Uvulae arise beside the posterior nasal spine and, like two closely applied fingers, they descend near the dorsum of the soft palate into the uvula, which they stiffen when they contract (*fig. 732*).

Vessels and Nerves of the Pharynx and Soft Palate. The pharynx is supplied by the *ascending pharyngeal a.*, the soft palate by the *ascending palatine branch of the facial a.*, and the tonsil by the *tonsillar branch of the facial a.* These anastomose with each other and with the *lesser palatine* and *dorsales linguae aa.* The naso-pharynx also receives the *pharyngeal a.* and the *artery of the pterygoid canal* which are branches of the maxillary a.

Veins go to the pharyngeal plexus, and thence to the internal jugular vein.

Lymph vessels pass to the upper deep cervical glands; those from the naso-pharynx pass to glands between the pharynx and the prevertebral fascia; those from the tonsil to a gland behind the angle of the jaw.

Motor Nerves. Nerve XI (through the vagus) via the pharyngeal plexus supplies all the pharyngeal and soft palate muscles, except

{Stylo-pharyngeus (nerve IX)
{Tensor Palati (nerve V^3).

The external and recurrent laryngeal branches of the vagus also supply Inf. Constrictor.

The Sensory Nerve of the pharynx, including the soft palate and tonsil, is the glosso-pharyngeal (IX). But the maxillary nerve (V^2), via its pharyngeal br., supplies the roof of the pharynx; and, via the lesser palatine nerves, helps to supply the soft palate and the adjacent part of the tonsil. The vagus (X) via the int. laryngeal nerve, supplies around the entrance to the larynx (*fig. 733*).

Mechanism of Swallowing. The lips are closed and the Buccinators compressed against the teeth. The lingual muscles pass the bolus of food to the base of the tongue. The Genio-hyoids raise and pull forwards the hyoid bone. The Mylo-hyoids force the tongue against the palate and with the Stylo-glossi shoot the bolus past the palatine arches

which by contracting narrow the entrance to the pharynx (i.e., oro-pharyngeal isthmus). The Constrictors force the bolus onwards and the Stylo-pharyngeus and Palato-pharyngeus draw the pharynx over it.

In the meantime 2 apertures are closed and 2 are opened:

(1) The entrance to the naso-pharynx (i.e., pharyngeal isthmus), rendered narrower by the contracting pharyngeal muscles, is closed by the Levatores Palati which draw the soft palate upwards and also backwards so that its upper surface is pressed against the wall of the narrowing pharynx. Lubricating mucus is necessary to render the isthmus air-tight. (Contrast the effectiveness of a hand pump when the plunger is wet and when dry.)

(2) The Tensores Palati now open the pharyngo-tympanic tubes; and, no doubt they also render taut the anterior parts of the soft palate.

(3) The entrance to the larynx is closed by the sphincter muscles (Arytenoid, Ary-epiglotticus, and Thyro-arytenoid) which tilt the apices of the arytenoid cartilages against the cushion of the epiglottis; and further, it is drawn upwards and forwards under shelter of the protecting base of the tongue. The epiglottis does not close like a lid on the larynx—in some animals, e.g., the bear, it is much too short to do so—but remains erect.

(4) The Crico-pharyngeus now relaxes its guard over the oesophageus to let food pass.

Cut away the soft palate, trace the S. Constrictor to the somewhat indefinite pterygo-mandibular ligament which connects it to the Buccinator. Detach the S. Constrictor but leave the M. Constrictor intact and trace the Stylo-glossus and Stylo-pharyngeus to their origins from the tip and medial aspect respectively of the styloid process. Remove some fatty tissue, follow the facial artery over the submandibular gland. Observe the Medial Pterygoid passing downwards, laterally and backwards, and the lingual and mylohyoid nerves appearing at its anterior border.

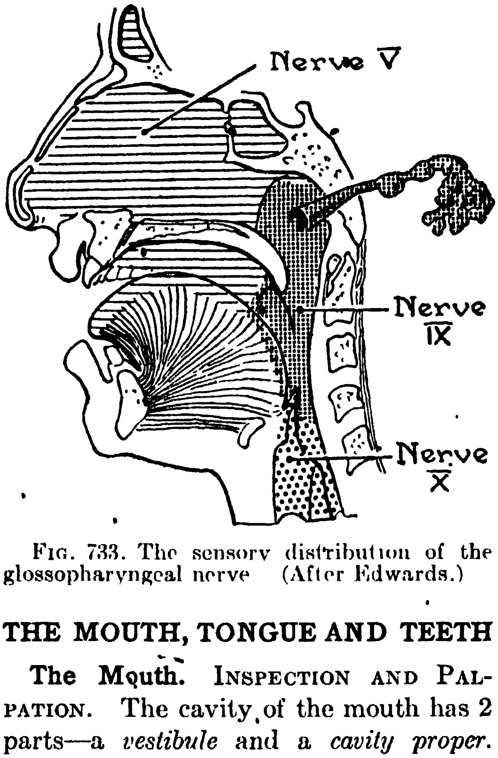


FIG. 733. The sensory distribution of the glossopharyngeal nerve (After Edwards.)

THE MOUTH, TONGUE AND TEETH

The Mouth. INSPECTION AND PALPATION. The cavity of the mouth has 2 parts—a *vestibule* and a *cavity proper*. These are separated from each other by the teeth, alveolar processes, and gums; and they communicate with each other on each side through a space between the last molar teeth and the ramus of the mandible.

THE VESTIBULE is bounded externally by the lips and cheeks. It opens on to the skin surface at the *aperture of the mouth.* The upper and lower lips are attached to the jaws in the median plane by folds of mucous membrane, the *frenula* of the lips. The constricted orifice of the parotid duct opens opposite

the 2nd upper molar tooth, but is hard to see.

The Lips have 4 layers: *cutaneous, muscular, glandular,* and *mucous,* and an arterial circle between the muscular and glandular layers. The pulsations of the *arterial circle,* formed by the upper and lower labial branches of the facial artery, can be felt on grasping the lip between the finger and thumb. The *glands* can be felt with the tip of the tongue and can be seen when the lip is everted. *The cheek* has the same 4 layers as the lips together with the buccal pad of fat, molar glands, and bucco-pharyngeal fascia. Where the *facial artery* crosses from lower to upper jaw, it is applied to the Buccinator an inch or less from the angle of the mouth, and its pulsations can be felt between the finger and thumb.

With the index finger in the vestibule *palpate* (a) the *Mentales,* passing from lower incisive fossae to the skin of the chin; (b) the lower border of the zygomatic process of the maxilla and of the *zygomatic arch,* and the facial and infratemporal surfaces of the maxilla; (c) the anterior border of the *ramus of the jaw,* tracing it to the coronoid process and to the tendon of the Temporalis; and (d) the *Masseter,* which is rendered prominent when the teeth are alternately clenched and relaxed.

Nerve Supply. The *motor* nerve is the facial. When it is paralyzed the lips cannot be moulded to whistle, and food collects in the vestibule. *Sensory:* The skin and mucous surfaces of the upper lip, lower lip, and cheek near the angle of the mouth are supplied by the infra-orbital (V^2), mental (V^3), and buccal (V^3) nerves respectively. *Lymph vessels (p. 776).*

THE CAVITY PROPER OF THE MOUTH is roofed in by the hard and soft palates. The anterior ⅔ of the *tongue* rises from the floor and covers the structures on the sides and front of the floor, known as the sublingual region. The *soft palate* ends medianly in the *uvula.* Two folds on each side arch downwards from the soft palate: the anterior fold, the *palato-glossal arch,* ends at the side of the tongue and marks the *oro-pharyngeal isthmus* or the entrance to the pharynx; on looking beyond it into the pharynx the posterior fold, the *palato-pharyngeal arch,* is seen to pass from the margin of the uvula to the side wall of the pharynx. Between these two palatine arches and the posterior ⅓ of the tongue a portion of the *palatine tonsil* is seen, and on the posterior wall of the pharynx some *lymphoid follicles* may stand out.

THE FLOOR. Rising from the floor is the anterior ⅔ of the tongue; below the tongue on each side and in front is the *sublingual region.* The dorsum of the anterior two-thirds of the tongue is covered with pointed filiform papillae amongst which the globular heads of *fungiform papillae* lie, scattered like daisies on a lawn. When the tongue is raised, its sides and under surface are seen to be smooth; a median fold, the *frenulum linguae,* connects it to the floor of the mouth. The *lingual vein* stands out blue and prominent on each side. Lateral to it is a *fimbriated fold.* The orifice of the *submandibular duct* opens beside its fellow on the floor at the root of the frenulum. Running postero-laterally from the orifice is a rounded ridge, the *plica sublingualis,* which overlies the upper border of the sublingual salivary gland.

With the index finger *palpate* (a) the anterior border of the Medial Pterygoid lateral to the palato-glossal arch; (b) the tuberosity of the maxilla behind the 3rd upper molar tooth; (c) the hamulus postero-medial to the tuberosity and below the level of the palate; (d) roll the

lingual nerve against the jaw medial to the root of the lower 3rd molar tooth; (e) grasp the tongue at the fimbriated fold and feel the pulsations of the lingual artery.

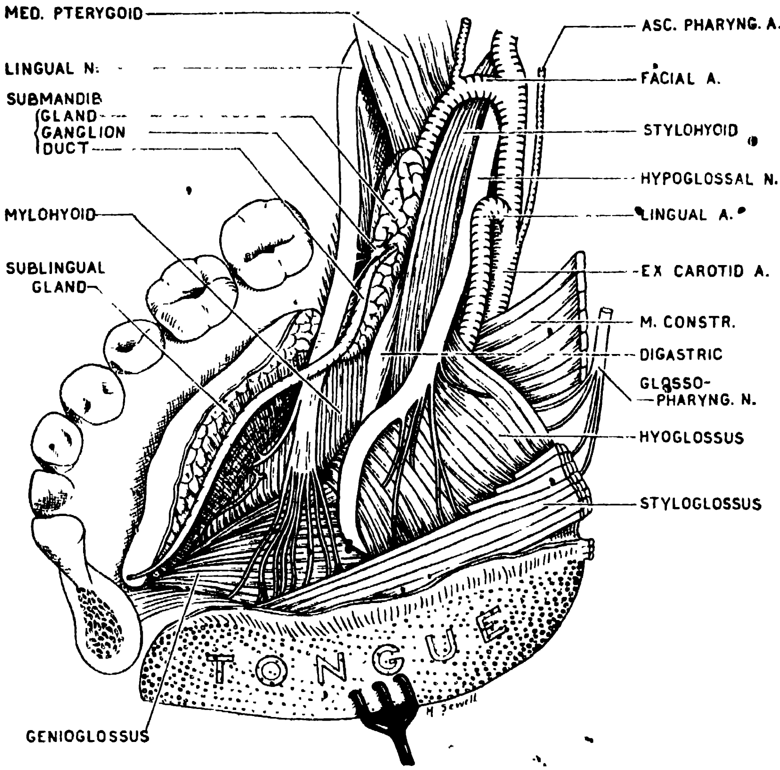


FIG. 734. Dissection of right side of floor of mouth.

DISSECTION OF THE FLOOR OF THE MOUTH.

Pull the right half of the tongue medially. Incise the mucous membrane along the bottom of the furrow between the mandible and the plica sublingualis and, keeping close to the bone, prolong the incision backwards to the 2nd molar tooth, and forwards to the frenulum (*fig. 734*). With the handle of the knife displace the sublingual gland (and with it the tongue) medially, but avoid injuring the lingual nerve which lies behind the incision. The fossa on the jaw for the sublingual gland is exposed, and below it the origin of the Mylohyoid is seen. Next, incise the mucous membrane along the bottom of the furrow between the plica sublingualis and the tongue, and with the handle of the knife displace the gland laterally. The extensive fan-shaped muscle displayed, passing from genial tubercle to the tongue, is the Genio-glossus. There being no concealing fat, the structures within the mouth are readily displayed with the aid of two pairs of forceps and occasional touches with the knife.

The Sublingual Salivary Gland is enveloped in a sheath of areolar tissue which like a mesentery fixes it to the floor of the mouth. The artery to the gland, the sublingual branch of the lingual artery, reaches it through the "mesentery". Running diagonally across the medial aspect of the sublingual gland and adhering to it is the *submandibular duct*. On teasing between the upper border of the sublingual gland and the

plica, a row of a dozen *short ducts* is seen leaving the gland to open on the plica.

In front, the sublingual gland is in contact with its fellow of the opposite side.

Behind, it abuts against the *submandibular* (submaxillary) *salivary gland*.

Laterally, it occupies the sublingual fossa of the jaw.

Medially, the submandibular duct and the lingual nerve pass between it and the Genioglossus (and Hyoglossus).

Below it is the Mylohyoid.

COMPARISON. The floor of the mouth may be likened to the floor of the pelvis. Thus -

The lower jaw	– the hip bones.
The symphysis menti	= the symphysis pubis.
The Mylohyoid (Diaphragma Oris)	– the Levator Ani. – (Diaphragma Pelvis).
The tongue	– the bladder
The mucous membrane and	– the peritoneum
The space between tongue and jaw	– the retropubic space.

The Lingual Nerve (*fig. 734*) is a branch of nerve V^3. It appears in the mouth from under cover of the S. Constrictor, behind the last molar tooth, and has the chorda tympani incorporated with it. When the S. Constrictor is detached from the pterygo-mandibular lig., the nerve is seen to be clamped to the ramus of the jaw by the Medial Pterygoid.

The lingual nerve passes from the lateral wall of the mouth, across the floor, to the side of the tongue. In its course it *describes a spiral* around the submandibular duct, lying successively above, laterally, below, medially, and above. Finally, it spreads out within the anterior $\frac{2}{3}$ of the tongue as the nerve of general sensation, its fibers ending mainly in the filiform and fungiform papillae. It also supplies the sublingual region, including the floor of the mouth and the gums. As it crosses the Hyoglossus, two stout branches pass between it and the submandibular ganglion (see below). (*Also figs. 678, 692, 744.*)

The Chorda Tympani, which joined the lingual nerve in the infratemporal fossa, contains secretory fibers for the submandibular and sublingual salivary glands and taste fibers from the anterior $\frac{2}{3}$ of the tongue; so, having efferent and afferent fibers it may be called a mixed nerve. The *taste fibers* accompany the lingual nerve to the anterior $\frac{2}{3}$ of the tongue where they end in the taste buds; their cell station is the geniculate ganglion. The *secretory fibers* are preganglionic parasympathetic fibers whose cell station is the submandibular ganglion.

The Submandibular (*Submaxillary*) *Ganglion* is a parasympathetic ganglion—a relay station on the course of the efferent fibers of the chorda tympani. It is suspended from the lingual nerve by two roots and it lies on the Hyoglossus medial to the submandibular gland.

The *posterior root* (or *roots*) brings to the ganglion *secretory fibers* from the chorda tympani and *sensory fibers* from the lingual nerve, *sympathetic fibers* (vasoconstrictor) join it from the plexus on the facial artery.

Branches of the ganglion are distributed directly to the submandibular gland and indirectly to the sublingual gland; the branches to the sublingual gland traversing the *anterior root* to be distributed via the lingual nerve.

The Hypoglossal Nerve runs forwards between the submandibular gland and the Hyoglossus well below the lingual nerve. As it crosses the Hyoglossus, fibers radiate to supply the extrinsic muscles of the tongue; at the anterior border of the Hyoglossus, it plunges into the tongue to supply the intrinsic muscles.

Muscles. The *Mylohyoids* (right and

left) arise from the mylohyoid lines on the mandible and they are inserted into the body of the hyoid bone. Their anterior borders are united in a median raphé that extends from the symphysis menti to the hyoid. The two Mylohyoids constitute the *Diaphragma Oris*.

Note the Mylohyoid has a free posterior border which indents the submandibular gland giving it a U-shape, just as the Levator Palpebrae indents the lacrimal gland. A small part, then, of the submandibular gland is in the mouth, a large part in the neck.

Nerve supply.—The mylohyoid branch of the mandibular nerve. (For further details see page 690.)

The right and left *Genioglossi* arise from the upper genial tubercles and, like two vertically placed fans, pass backwards into the tongue—their medial surfaces being in contact with each other. The right and left *Geniohyoids* arise from the lower genial tubercles and, like two horizontally placed fans, pass backwards to the body of the hyoid bone (*fig. 795*)—their medial borders being in contact with each other; they lie below the tongue.

Nerve supply.—Genioglossus by the hypoglossal nerve. Geniohyoid by C.1 via the hypoglossal nerve.

TONGUE

Form and Structure. The tongue is a muscular organ concerned with mastication, deglutition, speech, and taste. It has 2 parts—an anterior $\frac{2}{3}$ and a posterior $\frac{1}{3}$. These differ topographically, developmentally, structurally, functionally, in nerve supply, and in appearance. The anterior $\frac{2}{3}$ rises from the floor of the mouth and hence is called the *oral part* (body); the posterior $\frac{1}{3}$ forms part of the anterior wall of the pharynx and hence is called the *pharyngeal part* (root). The boundary between the oral and pharyngeal parts is marked on the dorsum of the tongue by a V-shaped line, the *sulcus terminalis*, which runs backwards on each side from where the palato-glossal arch joins the side of the tongue to a median pit, the *foramen cæcum linguae*. A mucous membrane of stratified squamous epithelium resting on a fibrous stroma, the *tunica propria*, covers the *dorsum* or upper surface of both parts of the tongue, as well as the tip, lateral margins, and under surface of the oral part. It is firmly adherent except on the posterior third of the dorsum where a submucous coat is present.

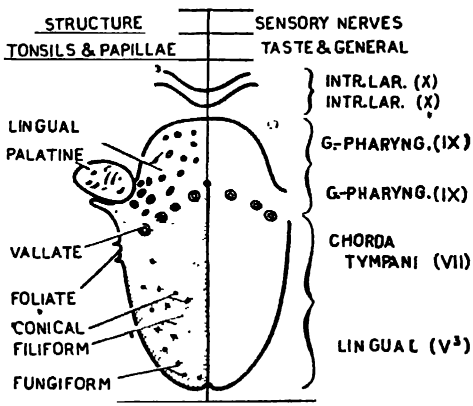


Fig. 735. The dorsum of the tongue showing (A) structure, (B) sensory nerve supply.

Two loose, median, crescentic folds of mucous membrane, one fore and the other aft, are attached to the tongue. The anterior fold, the *frenulum linguae*, passes from its under surface to the floor of the mouth and separates the orifices of the submandibular ducts; the posterior fold, the *glosso-epiglottic fold*, passes from its dorsum to the epiglottis and separates the valleculae.

The Mucous Membrane (*fig. 735*) covering the dorsum of the two parts is conspicuously different: on the *oral part* it is covered with papillae and is velvety; on the *pharyngeal part* it is studded with tubercles between which it is smooth and glistening. The papillae are of four

varieties, called filiform, fungiform, vallate, and foliate. They consist of a fibrous core derived from the tunica propria, covered with stratified squamous epithelium. The *filiform papillae* are tapering and thread-like and are arranged in V-shaped rows that cover the dorsum of the oral part of the tongue. They contain touch corpuscles. Their epithelium is scaly and in some animals (e.g., cat, cow) it is cornified and is used as a rasp to grasp food. The *fungiform papillae* have globular heads and are red because the core is more vascular and the epithelium not scaly. They are scattered singly among the filiform papillae at the tip and margin of the tongue, but they do not rise above them The *vallate papillae* are circular, about 2 mm. in diameter, and are surrounded by a moat which is 2–3 mm. deep. Twelve or less in number, they also are arranged in a V-shaped row just in front of the sulcus terminalis. Their flat tops hardly rise above the general surface. The *foliate papillae,* rudimentary in man, are 3 4 vertical folds at the hinder part of the side of the tongue. *Taste buds* occur on most fungiform papillae, on the opposed sides of the foliate, and on both walls of the vallate. They also occur sparsely on the soft palate, epiglottis, and posterior wall of the pharynx. Taste sensations (salt, acid, bitter, and sweet) are probably also mediated by free nerve endings within the epithelium of these regions.

The mucous membrane of the dorsum does not slip, because the tunica propria is continuous on the one hand with the cores of the papillae and on the other hand with the areolar tissue between the muscle fibers of the substance of the tongue.

On the *pharyngeal third* of the tongue there are no papillae. The numerous tubercles seen there are encapsuled *lymphoid nodules.* Each nodule surrounds a crypt, which receives the ducts of underlying mucous glands and opens conspicuously on the surface at the center of the nodule. The nodules are known collectively as the *lingual tonsil* They are indefinitely separated from the lower pole of the palatine tonsil.

The mucous membrane on the under surface of the tongue is smooth, and the lingual vein shines purple through it. Lateral to the vein is the *plica fimbriata.*

The Anterior Lingual Gland (of Nuhn) is a cluster of mucous and serous racemose glands, half-an-inch long, situated one on each side under the apical part of the tongue. It has a covering of longitudinal muscle fibers below it; the terminal parts of the lingual artery and nerve run above it.

The Muscular Substance comprises 3 extrinsic and 3 intrinsic muscles on each side—all supplied by the hypoglossal nerve. The former move the tongue bodily and alter its shape; the latter only alter its shape.

The Extrinsic Muscles are—Genio-glossus, Hyo-glossus, and Stylo-glossus. Their actions are obvious. The middle and posterior fibers of the Genio-glossi protrude the tongue; the anterior fibers withdraw the tip. The Stylo-glossi withdraw and raise the tongue. The Hyo-glossi draw the sides downwards and backwards. The Genio-glossi as protruders of the tongue are *"safety muscles"*, and if put out of action—the result of paralysis, fracture of the jaw, partial excision in case of cancer, or during anesthesia—the tongue falls back and suffocation results. If only one Genio-glossus is paralyzed, the protruded tongue is thrust to the paralyzed side.

The Intrinsic Muscles are—Longitudinalis, Verticalis, and Transversus. The longitudinal fibers are in part at-

tached posteriorly to the hyoid bone. They form an incomplete outer cortex deep to the tunica propria. The transverse and vertical fibers decussate with them; so do the extrinsic fibers.

Accessory Muscles. (a) The *Palato-glossus*, supplied by nerve XI via the vagus, though primarily a palatine muscle, helps to narrow the oro-pharyngeal isthmus during the act of swallowing. (b) The *Genio-hyoid*, by pulling the hyoid or tongue-bone forwards, comes into play on swallowing, as you can determine on yourself by palpation. It is supplied by nerve C.1 via the hypoglossal nerve. (c) The *Chondro-glossus* is a slip of the Hyo-glossus that arises from the cartilaginous lesser horn of the hyoid bone.

Strangely there are *areas of fat* among the more posterior muscle fibers. The fibers are loosely bound together by areolar tissue and, so, are not hampered in action. The tongue has a median *fibrous septum* which is attached to the hyoid bone. It does not reach the dorsum.

The Lingual Artery alone supplies the tongue. It arises from the external carotid between the superior thyroid and facial arteries, sometimes forming a short common stem with one or other. The origin is at the level of the greater horn of the hyoid; therefore, the artery is applied to the M. Constrictor, which separates it from the mucous membrane of the pharynx. On leaving the M. Constrictor, it continues its course to the tip of the tongue applied to the Genio-glossus. Its other relations are superficial ones. Naturally, it is very tortuous. In the carotid triangle it arches upwards and is crossed by nerve XII which arches downwards. It passes deep to the posterior belly of the Digastric and Stylo-hyoid and enters the digastric triangle, where nerve XII crosses it again. It runs deep to the Hyo-glossus, which now separates it from nerve XII, and under cover of the anterior border of the Hyo-glossus, it ascends on the Genio-glossus. Finally, it runs tortuously deep in the furrow between the Genio-glossus and Longitudinalis Inferior.

In the last part of its course it is called the *profunda artery*. Its only anastomosis with its fellow is at the tip of the

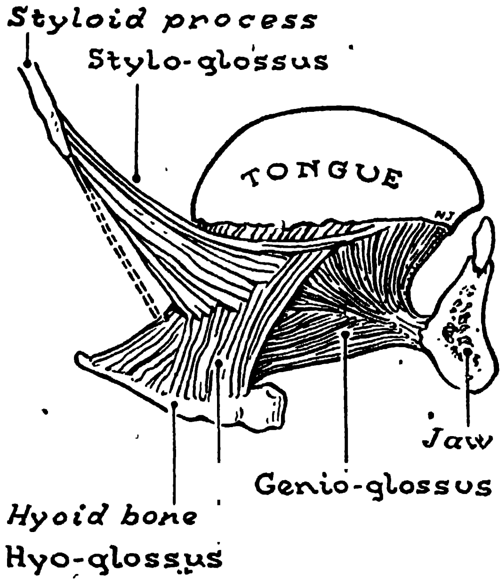


Fig. 736. The 3 extrinsic muscles of the tongue and their 3 bony origins.

tongue; so, the tongue can be bisected almost bloodlessly.

Branches. A *suprahyoid twig; two dorsales linguae aa.*, which ascend deep to the Hyo-glossus to supply the posterior third of the tongue and anastomose in the tonsil bed (*p. 730*); numerous muscular twigs; and a *sublingual a.*, which supplies the sublingual gland and floor of the mouth and sends a branch to the frenulum; it anastomoses with the submental branch of the facial a. (*figs. 670, 668, 734*).

Small *venae comitantes* accompany the lingual artery, but the chief vein of the

tongue (the profunda vein) is the conspicuous submucous vein. It follows nerve XII across the Hyo-glossus, and is then joined by the venae comitantes to form the lingual vein which ends in the internal jugular vein.

THE LYMPH VESSELS of the two sides anastomose in the tongue and at the front of the floor of the mouth. They pass to the submental and submandibular glands and to the cervical glands between the levels of the Digastric and Omo-hyoid. The upper gland of this series is called the *jugulo-digastric*, the lower gland the *jugulo-omohyoid*, the gland at the bifurcation of the common carotid artery is called the *principal gland of the tongue*. The lymph vessels from the tip pierce the Mylo-hyoid and end in the submental, submandibular, and jugulo-omohyoid glands; those from the margin pierce the Mylo-hyoid and end in the submandibular glands or follow the lingual vessels across the Hyo-glossus to the jugulo-digastric and jugulo-omohyoid glands. The central vessels descend in the median septum and, anastomosing with those of the opposite side, either pierce or pass below the Genio-glossus and follow the lingual vessels to the glands on both sides. The posterior vessels pass through the pharyngeal wall below the palatine tonsil and accompany the lymph vessels of the palatine tonsil to the upper glands of the series.

Development and Nerve Supply. Like the palate, the anterior ⅔ of the tongue has a bilateral origin. It develops from two ingrowing shelves, one on each side of the 1st or mandibular arch. This explains the nerve supply from the lingual branch of the mandibular nerve (V^3), and also why the tip is sometimes bifid, as is the serpent's tongue. With this part is incorporated posteriorly a median eminence, the *tuberculum impar*, which makes its appearance between the 2nd arches. This explains the nerve supply from the chorda tympani branch of the facial nerve. The posterior ⅓ of the tongue is unpaired. It develops from a median bar, the *hypobranchial bar*, placed between the ends of the 3rd and 4th arches. This explains the nerve supply from the glosso-pharyngeal and superior laryngeal nerves. The glosso-pharyngeal nerve supplies the vallate papillae and therefore encroaches on the territory of the chorda tympani nerve. The foramen cecum is the persisting end of the thyroglossal duct, and it marks the site of union of the anterior and posterior parts.

The muscles of the tongue are supplied by the hypoglossal nerve. Phylogenetically they are somatic muscles of the occipital region which have migrated forwards into both parts of the tongue.

Afferent Nerves. The *lingual nerve* is for general sensation, the *chorda tympani* is for taste, the *glosso-pharyngeal* and *superior laryngeal nerves* are for general sensation and for taste.

TEETH

PARTS (*fig.* 737). Each tooth has a root buried in the jaw, a *crown* projecting beyond the gum, and a *neck* encircled by the gum. At the apex of each root a pinpoint foramen, the *apical foramen*, leads through a widening *root canal*, to the *pulp cavity*.

Each tooth is composed of *dentine* which is the exquisitely sensitive, yellowish basis of the tooth; *enamel*, which is the white insensitive covering of the crown, *cement* (crusta petrosa) which is a bony covering for the root and neck of the tooth; and *pulp* which is a fibrous material containing the nerves and vessels that pass through the pinpoint, apical canal. The pulp occupies the pulp cavity within the dentine.

Each tooth lies in a bony socket or *alveolus* which narrows towards its bottom; thus a large pressure surface is afforded and tooth extraction made possible. Between the tooth and the socket there is a vascular membrane, the *periodontal membrane*, which is continuous with the lamina propria of the gum and is attached both to the cement and to the alveolar wall.

There are *32 permanent teeth*, sixteen in the upper dental arch and sixteen in the lower. Of the eight on each side of each arch—two are incisors, one canine, two bicuspids, and three molars. The formula therefore reads:

$$\frac{3.\ 2.\ 1.\ 2.\ \big|\ 2.\ 1.\ 2.\ 3.}{3.\ 2.\ 1.\ 2.\ \big|\ 2.\ 1.\ 2.\ 3.}$$

All except the molars are preceded by temporary or deciduous teeth.

There are *20 temporary, deciduous*, or *milk teeth*——two incisors, one canine, and two molars on each side of each arch. The formula therefore reads:

$$\frac{2.\ 1.\ 2.\ \big|\ 2.\ 1.\ 2.}{2.\ 1.\ 2.\ \big|\ 2.\ 1.\ 2.}$$

Eruption. At birth, the jaws are rigid bony bars, suitable to grasping a nipple. Between the 6th and 9th months the lower medial incisors erupt through the gums, and eruption proceeds in the following order:—lower medial incisors, upper medial incisors, upper lateral incisors, lower lateral incisors, first molars, canines, and second molars, the process being completed by the 24th month. There are 12 teeth, or fewer, at the 12th month.

Then comes an *interval of four years*. At the 6th year the permanent teeth begin to erupt, and, because the first molars are the first permanent teeth to erupt, they are commonly called the *sixth year molars*. The deciduous teeth are next replaced by permanent teeth in the following order:—medial incisors, lateral incisors, first bicuspids, second bicuspids, and canines. The second molars erupt about the twelfth year and the third molars about the eighteenth year, but sometimes much later, and commonly they fail to erupt.

Descriptive Terms. It is convenient to refer to the anterior surfaces of the front teeth and lateral surfaces of the side teeth as *labial* (or buccal) surfaces; and to refer to the opposite surfaces as *lingual* (or palatine) surfaces; to refer to

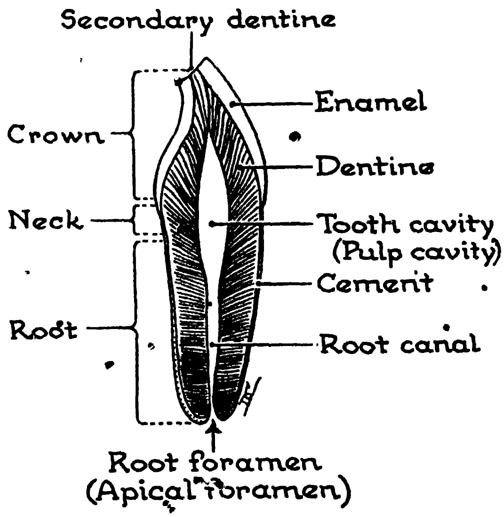


FIG. 737. A tooth, on longitudinal section.

the medial surfaces of the front teeth and anterior surfaces of the side teeth as *proximal* surfaces, and to the opposite surfaces as *distal* surfaces. The biting surfaces may be referred to as the *occlusal* surfaces. With the exception of the distal surfaces of the last molars, proximal and distal surfaces are *contact* surfaces.

CROWNS. There is evidence that the crowns of the human teeth have evolved from a tritubercular or tricuspid tooth. And two labial tubercles and one lingual tubercle are detectable on each tooth. In the *incisors*, the labial tubercles fuse to form a cutting edge which is joined

to an indistinct lingual tubercle by two faint lines (the cingulum) that enclose a triangular space. Among the North American Indians these are pronounced and give the incisors a shovel-like appearance. In the *canines*, the labial tubercles

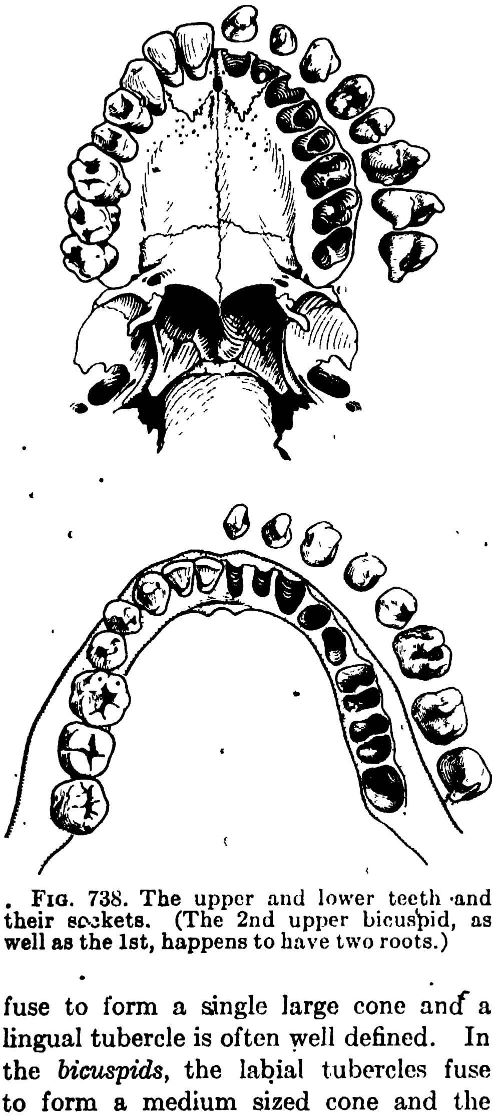


FIG. 738. The upper and lower teeth and their sockets. (The 2nd upper bicuspid, as well as the 1st, happens to have two roots.)

fuse to form a single large cone and a lingual tubercle is often well defined. In the *bicuspids*, the labial tubercles fuse to form a medium sized cone and the lingual tubercle or cusp is pronounced. All molars have as a basis two labial tubercles and a proximal lingual tubercle. The *upper molars* characteristically have an additional lingual tubercle placed distally, making four in all—the first molar always has four, the second commonly, and the third variably. The *lower molars* characteristically have five tubercles, two being labial, two lingual, and a fifth distal—these tend to be reduced on the third lower molar.

Roots (*fig. 738*). The roots of the incisors, canines, and bicuspids are single. (The first upper bicuspid has commonly a bifid or even a double root.) The lower molars have two flattened roots, a proximal and a distal; the upper molars have three conical roots, two smaller labial and one larger lingual. The roots of all teeth tend to be flattened proximo-distally, and in all lower teeth the flattening is pronounced. In the upper teeth there is a compromise between being rounded and conical on the one hand and being flattened on the other. The upper medial incisor has the roundest root; the canines have the longest roots; and the roots of the molars are commonly recurved.

Occlusion. The teeth of the upper arch project labially beyond the teeth of the lower arch. As a result, the labial borders of the occlusal surfaces of the lower bicuspids and molars tend to be worn off and rounded and the lingual borders are sharp. The reverse is true of the upper bicuspids and molars. The upper incisors in most races "overbite" the lower incisors and do not come into occlusion (*fig. 739*).

The upper and lower dental arches end flush with each other posteriorly (*fig. 739*). The upper medial incisors are relatively large and the third upper molars relatively small; so, when the arches are in occlusion most teeth bite on two teeth.

When smiling, the incisors, canine, and bicuspid teeth are in view; so, they are prized more highly than the molars which remain hidden.

The Enamel is of ectodermal origin. It begins to develop during the third fetal month from buds that sprout from an ingrowing plate (the primary dental lamina) of ectodermal cells. Each takes the form of a cap that covers the mesodermal papilla from which the remainder of the tooth is formed. At the same time buds, from which the enamel of the corresponding permanent teeth arises, sprout from the lingual surface of the dental plate, but they remain quiescent temporarily. The three permanent molars develop similarly from a backward extension of the plate, the 1st beginning at the fifth fetal month, the 2nd at the fourth month after birth, and the 3rd at the fifth year; so, prenatal disturbances can affect the sixth year molars.

Nerve Supply to the Teeth and Gums. The maxillary nerve (V^2) supplies the teeth and gums of the upper jaw; the mandibular nerve (V^3) supplies those of the lower. (*Figs. 740, 741*).

The teeth of the *upper jaw* and also their periodontal membranes are supplied by the posterior and anterior superior dental branches of the maxillary nerve. The internal (palatine) part of the upper gum related to the molars and bicuspids is supplied by the greater palatine nerve; the part related to the canine and incisors by the long spheno-palatine nerve. The external (buccal) part of the upper gum related to the molars is supplied by branches of the posterior superior dental nerve (which descend on the infratemporal surface of the maxilla); the part related to the bicuspids, canine, and incisors by the infra-orbital nerve. (See the infra-orbital nerve, p. 750).

The teeth of the *lower jaw* and their periodontal membranes are supplied by the inferior dental branch of the mandibular nerve. The entire internal (lingual) part of the lower gum is supplied by the lingual nerve. The external (buccal) part related to the molars and bicuspids is supplied by the buccal branch of the mandibular nerve, the part related to the canine and incisors by the mental nerve.

Variations in Distributions: (a) The pulp of the lower teeth may retain residual sensation after injection of the inferior dental nerve; there is evidence to show that this is mediated by fibres of the lingual and buccal nerves which pierce the internal and external alveolar walls to reach the pulp; (b) branches of the inferior dental nerve to the incisor teeth may decussate in the mandibular canal with those of the opposite side and supply the opposite incisors; (c) similarly, branches of the mental nerves of opposite sides decussate in front of the symphysis menti and supply the gum of the opposite side; (d) the anterior limits of the dis-

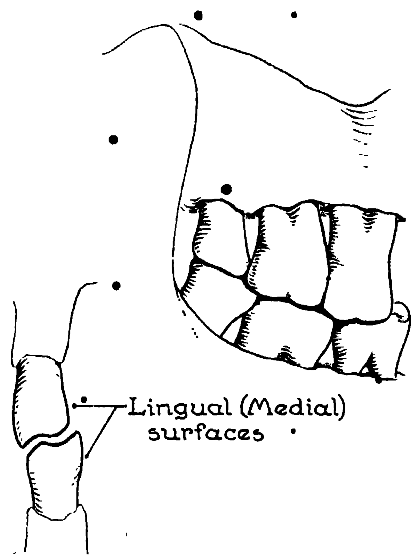


FIG. 739. The right molar teeth in occlusion. Except for the lower central incisor and the third upper molar (i.e., the proximal tooth in the lower row and the distal tooth in the upper row) which are small, each tooth comes into occlusion with two teeth.

tribution to the gums of the lingual and buccal nerves varies, as is evidenced by loss of sensation on injecting these nerves. Thus, the lingual nerve, though usually extending to the median plane, sometimes stops abreast of the canine tooth, and the lingual nerve of the opposite side crosses to supplement it. Similarly, the buccal nerve distribution may cease at the anterior border of the 2nd molar or extend to the middle of the canine; the posterior

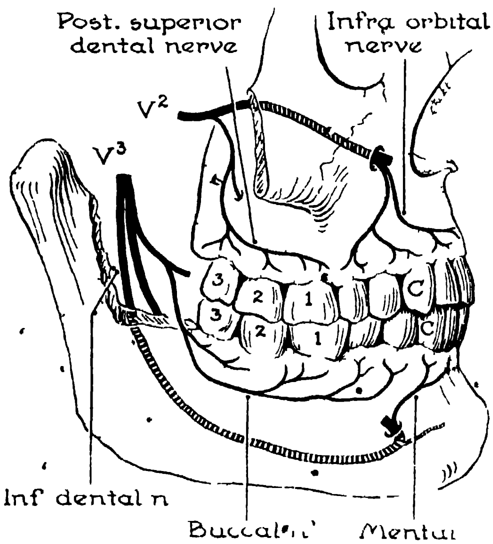


FIG. 740. Nerve supply to the outer aspect of the gums.

limits of the mental nerve vary inversely with this. (Stewart and Wilson.) Doubtless, similar variations occur in the nerves to the upper teeth and gums.

The *lymph vessels* of the pulp of the teeth pass to the submandibular and upper deep cervical glands.

PTERYGO-PALATINE FOSSA, NASAL CAVITIES AND PARANASAL SINUSES

The Pterygo-palatine Fossa is the elongated triangular interval between the rounded posterior border of the maxilla and its buttress, the *pterygoid process.* The vertical plate of the palatine bone forms its medial wall; the greater wing of the sphenoid forms its roof. The *spheno-palatine foramen,* as might be inferred from its name, is situated at the junction of the roof and medial wall (*figs. 743, 746*). It is large and round, and is the main door for the vessels and nerves to the nasal cavity. A wire or a bristle passed through the foramen follows the

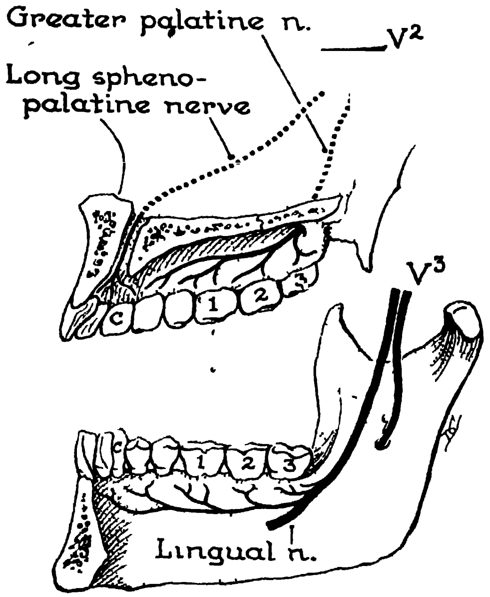


FIG. 741. Nerve supply to the inner aspect of the gums. Branches also reach the gums between the tooth sockets (*fig. 742*).

roof of the nose on to the nasal septum. Thin wires or bristles passed up the *greater* and the *lesser palatine canals* enter the fossa from below. Wires passed through the *foramen rotundum* and *pterygoid canal* enter it from behind. The pterygoid canal is demonstrated by passing a bent wire forwards from a point immediately supero-lateral to the pterygoid tubercle (*p. 705*).

The fossa communicates with the orbit through the hinder part of the *inferior orbital fissure,* and with the infratemporal

fossa through the *pterygo-maxillary fissure*. Its contents are:

(a) the maxillary nerve (in part),
(b) the spheno-palatine ganglion,
(c) the maxillary artery (3rd part) and veins.

The Maxillary Nerve (*figs. 742, 743*), (V^2) or 2nd division of the trigeminal nerve, arises from the trigeminal ganglion and is purely sensory. It is distributed to what developmentally is the maxillary process. The wavy route it takes may be indicated by threading a wire from the middle cranial fossa through the foramen rotundum, across the pterygo-palatine and infratemporal fossae to the inferior orbital fissure, thence through the infra-orbital sulcus, canal, and foramen to the face. (On entering the infra-orbital sulcus it is called the infra-orbital nerve.) In the cranium the nerve runs along the infero-lateral border of the cavernous sinus; in the foramen rotundum it commonly creates a ridge on the floor of the sphenoidal air sinus; in the pterygo-palatine fossa it is surrounded by branches of the 3rd part of the maxillary artery and veins, and the spheno-palatine ganglion is suspended from it; in the infra-orbital sulcus and foramen it creates a ridge on the roof and anterior wall of the maxillary air sinus.

Branches. (1) *A meningeal twig* goes to the dura mater. (2) An *orbital twig* supplies the periorbita and conveys sympathetic fibers to the involuntary orbital *muscle of Muller*, which bridges and extends beyond the margins of the inferior orbital fissure. This muscle is extensive in mammals that lack a bony partition between the orbital and temporal fossae. Perhaps spasm of this muscle is one cause of exophthalmos. (3) *Two roots* go to the spheno-palatine ganglion. (4) *The zygomatic nerve* passes through the inferior orbital fissure to the orbit, enters a V- or Y-shaped canal in the zygomatic bone, from which it emerges as two cutaneous branches, the *zygomatico-facial*

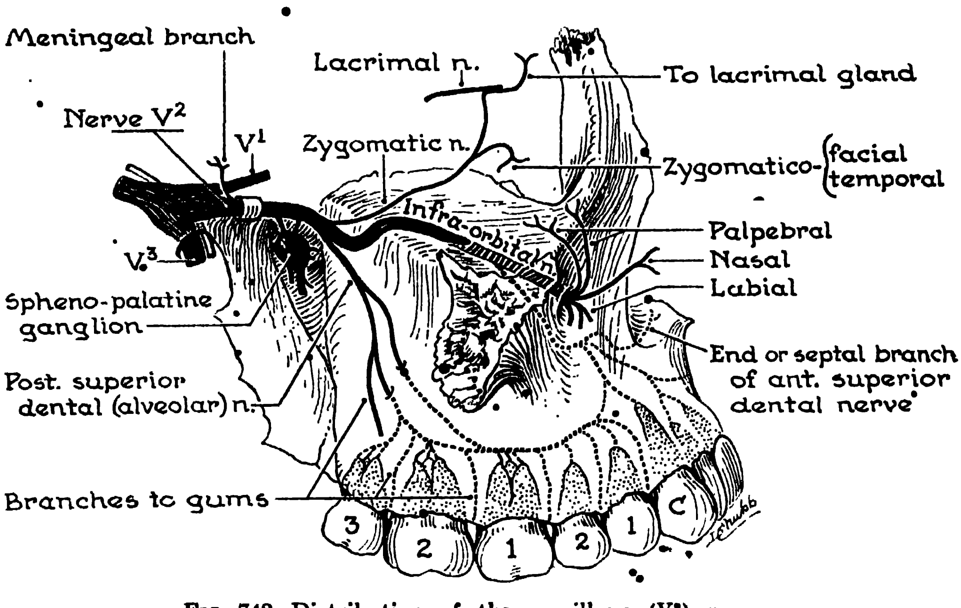


FIG. 742. Distribution of the maxillary (V^2) nerve.

and *zygomatico-temporal*; one on the cheek, the other in the temporal fossa (*fig. 621*). The secretory fibers to the lacrimal gland travel with the zygomatic nerve into the orbit, and there, leaving it, ascend on the lateral wall of the orbit to join the lacrimal nerve, which conveys them to the gland.

THE INFRA-ORBITAL NERVE is the continuation of nerve V^2. It begins at the inferior orbital fissure and ends on the face, between the Levator Labii Superioris and the Levator Anguli Oris (Caninus),

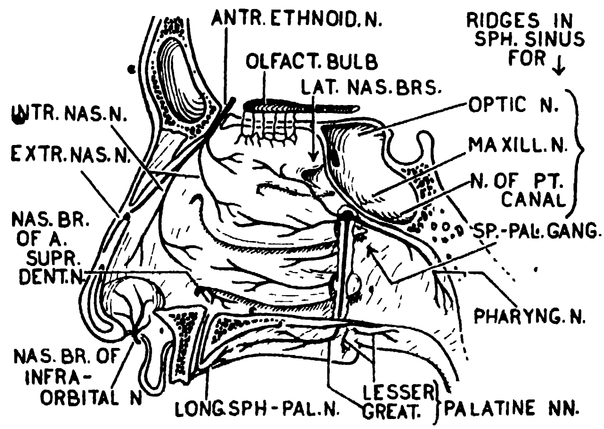


FIG. 743. The nerves of the nose and palate.

by dividing into many branches (*fig. 621*) which radiate to the cutaneous and conjunctival surfaces of the lower eyelid, to the skin of the side of the nose, to the vestibule of the nose, to the mobile part of the nasal septum, to the cutaneous and mucous surfaces of the upper lip and cheek, and to the gum.

In its course, it gives off 2 branches which are called the posterior and anterior *superior dental (alveolar) nerves*. These descend in the infratemporal and facial walls of the maxilla—which are almost eggshell in thinness—and there form loops from which twigs proceed to the teeth, periodontal membranes, and mucous membrane of the maxillary sinus. The molar and bicuspid teeth are supplied by the posterior nerve, and the canine and incisor teeth by the anterior nerve.

The posterior superior dental nerves (usually two) arise in the infratemporal fossa [and therefore strictly speaking from the end of nerve V^2] and, descending, supply twigs to the buccal portion of the gum over the molar teeth before entering their canals about the center of the infratemporal surface of the maxilla. *The anterior superior dental nerve* curves medially below the infraorbital foramen and is apt to be damaged in opening into the maxillary sinus from the front; it sends a twig to the inferior meatus and floor of the nose (*fig. 742, 743*).

The Spheno-palatine Ganglion is a parasympathetic ganglion situated in the upper part of the pterygo-palatine fossa. It is best displayed by breaking down the papery medial wall of the fossa. It is described as having three roots: secretory, sympathetic, and sensory; but it is essentially a relay station on the secretory pathway of the greater superficial petrosal branch of the facial nerve, which reaches the ganglion as the nerve of the pterygoid canal. The other roots pass through the ganglion without interruption (*fig. 744*).

The *sensory root* consists of two stout bundles that descend from nerve V^2 to the ganglion in order to be joined by the secretory and sympathetic fibers. The composite nerve so-formed is distributed to the mucosa of the nasal cavity, naso-pharynx, and palate as follows:

Through the Spheno-palatine Foramen pass three nerves: (1) *Short spheno-palatine nerves* run forwards to the upper

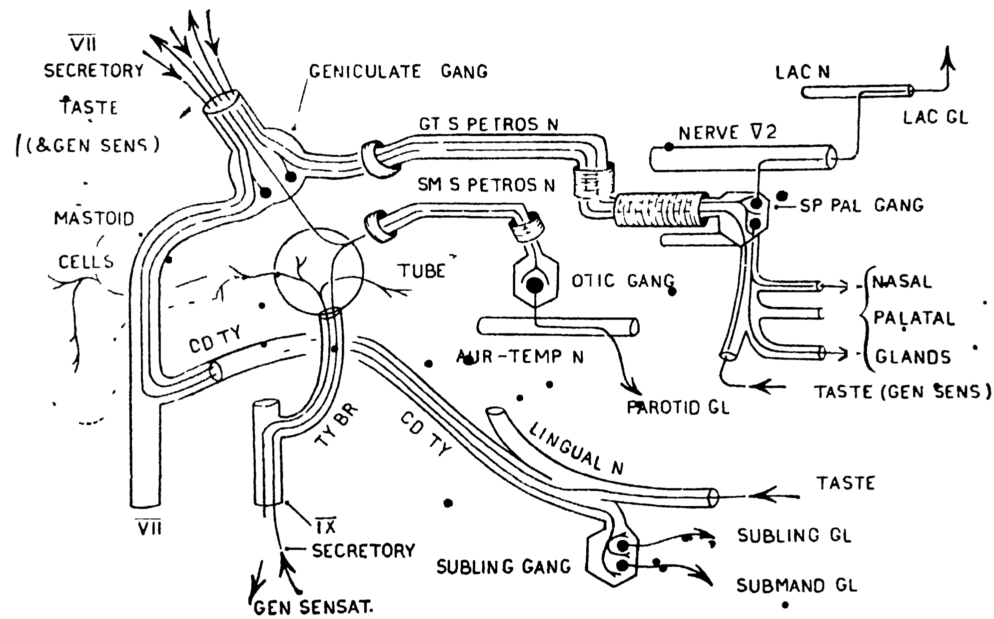


FIG. 714. Anatomic ganglia on the branches of nerves VII and IX: spheno-palatine, otic, and submandibular (sublingual)

parts of the side wall of the nasal cavity (upper lateral nasal branches) and to adjacent parts, namely, the roof, septum, and ethmoid cells. (2) *The long spheno-palatine nerve* (naso-palatine) crosses the under surface of the body of the sphenoid and, reaching the nasal septum, descends in the muco-periosteum in a groove on the vomer to the incisive foramen, through which it passes. It supplies the septum, under surface of the front of the hard palate, and the gum. (3) *The pharyngeal nerve* runs backwards to supply the roof of the naso-pharynx and the sphenoidal sinus. It occupies the groove or canal on the under surface of the vaginal process of the medial pterygoid plate.

Through the Greater Palatine Canal the Greater Palatine Nerve descends to the under surface of the hard palate medial to the 3rd molar tooth. Thereafter, as two branches, it runs forwards in the muco-periosteum near the alveolar arch and supplies the remainder of the hard palate and the palatine portion of the gum. It gives off (a) *two nasal branches,* (lower lateral nasal nerves), which pierce the vertical plate of the palatine bone and pass forwards to the inferior concha and inferior meatus; and (b) *two lesser palatine nerves* which traverse the lesser palatine canals in the tubercle of the palatine bone. They appear close behind the parent nerve and supply the mucous membrane of the soft palate and adjacent parts of the tonsillar region.

The sympathetic fibers, which are mainly

vaso-constrictor, pass from their cell station in the superior cervical sympathetic ganglion through the carotid canal to the foramen lacerum, where (as the deep petrosal nerve) they leave the carotid artery and join the *secretory fibers* (greater superficial petrosal nerve) to form the nerve of the pterygoid canal.

The Nerve of the Pterygoid Canal passes forwards through its canal to the spheno-palatine ganglion and there, after being relayed, is conveyed with the various sensory branches to the glands of the nose, naso-pharynx, and palate; and some fibers travel with the zygomatic nerve, thence to the lacrimal nerve, and so to the lacrimal gland. The secretory root also contains a few *taste fibers* which are distributed to the soft palate. It has therefore the same composition as the chorda tympani and they both share the ganglion of the facial nerve (geniculate ganglion) as a cell station for taste fibers.

The 3rd Part of the (Internal) Maxillary Artery passes through the pterygo-maxillary fissure into the pterygo-palatine fossa and there breaks up into branches which accompany closely the branches of the maxillary nerve and of the spheno-palatine ganglion; so, all *its branches enter foramina.*

The *branches* are: posterior superior dental, infra-orbital, long and short spheno-palatine, pharyngeal, artery of the pterygoid canal, greater palatine (*fig. 697*).

The corresponding *veins* form the beginning of the pterygoid plexus of veins.

The Nasal Cavities

The right and left nasal cavities are situated above the hard palate and are separated from each other by the nasal septum. Each cavity has an anterior and a posterior aperture, a floor, roof, medial wall or septum, and a lateral wall (*figs. 725, 743*).

THE ANTERIOR APERTURE (nostril or naris) is directed downwards on to the face. It is oval, mobile, and kept patent by the U-shaped lower nasal cartilage (*figs. 613, 614*).

THE POSTERIOR APERTURE (choana) is directed backwards into the naso-pharynx. It is oblong, rigid, bounded by bone, 1″ high and $\frac{3}{4}$″ wide (*fig. 707*).

THE FLOOR, formed by the superior surface of the hard palate, is smooth, concave from side to side, half an inch or more wide, about three inches long from the tip of the nose to the posterior border of the septum, and nearly horizontal.

THE ROOF has: (a) an *anterior part* whose slope corresponds with the slope of the bridge of the nose (formed by the upper nasal cartilage, nasal bone, and spine of the frontal bone); (b) an *intermediate part*, formed by the cribriform plate, which is horizontal, 2-3 mm. wide, thin, delicate, and perforated by the olfactory nerves and ethmoidal vessels. It is situated beneath the anterior cranial fossa and is easily fractured, with consequent risk of meningitis. (c) *A posterior part* is formed by the anterior and the inferior surface of the body of the sphenoid, and has therefore a vertical and a sloping portion, which meet at an obtuse or a right angle. This part is about $\frac{1}{2}$ of an inch wide, and is confluent with the roof of the naso-pharynx.

Strip the muco-periosteum from the *nasal septum*.

THE NASAL SEPTUM OR MEDIAL WALL has 3 main skeletal parts (*fig. 745*):

1. The thin *vertical* (*perpendicular*) *plate of the ethmoid* lies above.
2. The *vomer* lies below and behind.
3. The *septal cartilage* lies in front and

extends backwards into the angle between the ethmoid and the vomer.

Slight *crests* on the palatine, maxillary, nasal, frontal, and sphenoidal bones form peripheral parts of the bony septum.

The posterior border of the vomer is free and extends from the posterior nasal spine to just in front of the junction of the basi-sphenoid and basi-occipital. The anterior part of the inferior border of the septal cartilage extends from the anterior nasal spine towards the apex of the nose; it, however, is not free, since below it the *mobile part* of the septum extends from the philtrum of the lip to the tip of the nose. The medial crura of the lower nasal cartilages stiffen it. This should be verified by inserting the tips of the thumb and index finger into the nostrils and feeling the lower border of the septal cartilage above the mobile septum.

Deflected Septum. If the septum is not quite straight, the deflection usually takes p'ace at the junction of the catilage with the vomer, and the bony and soft parts of the middle concha, on the concave side are enlarged, as though to reduce the excess space.

At Birth, except for a miniature vomer, the framework of the septum and of the crista galli are cartilaginous. The definitive septal cartilage remains cartilaginous; the vertical plate of the ethmoid (and crista galli) is converted into bone; but the cartilage which precedes the vomer disappears, the vomer developing in right and left halves from the perichondrium on each side of the primitive septal cartilage. The alae of the vomer and the groove along the upper border of the vomer into which the definitive septal cartilage fits bear evidence of this bilateral origin.

Proceed to remove the bony and cartilaginous parts of the septum, leaving the mobile septum and the muco-periosteum on the far side intact so that the arteries can be seen and the nerves perhaps dissected.

VESSELS AND NERVES. The *arteries* form an open network. Descending from above are the branches of the anterior and posterior ethmoidal arteries and of the olfactory and anterior ethmoidal nerves. Running in a groove on the vomer from the junction of the anterior and inferior aspects of the body of the sphenoid to the incisive foramen are the long

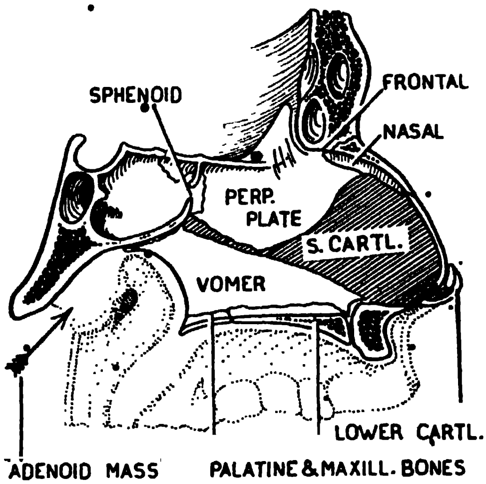


FIG. 745. The bones and cartilages of the nasal septum.

spheno-palatine nerve and artery. The nerve has already been traced through the incisive canal. A twig from the greater palatine artery ascends through the incisive canal; a twig from the superior labial artery ascends across the mobile septum. The infra-orbital nerve supplies the mobile septum.

The frontal and sphenoidal air sinuses of one side or other have likely been opened because, though these sinuses are bi-lateral structures, the septa between them are not usually in the median plane.

On the other half of the head (right side) inspect and dissect the lateral wall.

THE LATERAL WALL (*figs. 746, 747*). Two downwardly curved shelves, the *inferior* and *middle conchae*, project from the lateral wall of the cavity and divide it into three parts, approximately equal in depth. They conceal the *inferior* and *middle meatuses* A third shelf, the *superior concha*, extends obliquely from the middle of the root to the middle of the concha is free, horizontal, and extends backwards to within ½″ of the pharyngotympanic tube. The lower border of the middle concha is largely horizontal but with the addition of a short vertical or oblique anterior limb and, consequently, of an antero-inferior angle. It is on a level with the lower surface of the body of the sphenoid

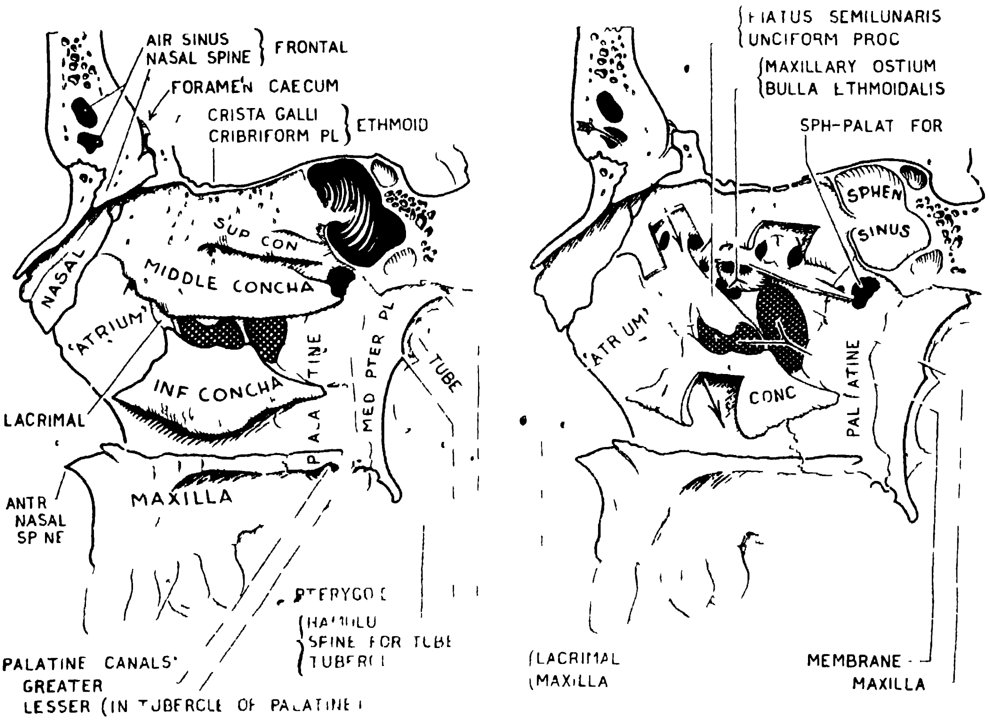


FIG. 746. A Bones of lateral wall of nasal cavity. B Parts of the conchae have been cut away to reveal the openings of the air sinuses. Arrows traverse the frontal air sinus and the naso-lacrimal canal.

front of the body of the sphenoid and conceals the *superior meatus*. The area above and behind it is known as the *spheno-ethmoidal recess*.

The inferior and middle conchae extend backwards almost to the naso-pharynx (the width of the medial pterygoid plate intervening) and forwards to a line joining the incisive foramen to the foramen caecum. The lower border of the inferior

The part of the nasal cavity between the conchae and the septum is the *meatus communis*. The part anterior to the conchae is divided into two areas—a *vestibule* and an *atrium*. The *vestibule*, or entrance chamber, lies in front of the inferior meatus, on the medial surface of the mobile ala of the nose. It is lined with stratified squamous epithelium, guarded by hairs, and lubricated by

sebaceous and sweat glands—in short, by skin. Further, as the *apical recess*, it extends forwards towards the tip of the nose. The U-shaped lower nasal cartilage keeps the vestibule patent. The *atrium* lies in front of the middle meatus and above the vestibule. A ridge or limen, caused by the upper edge of the lower nasal cartilage, separates the atrium from the vestibule It is lined with the muco-periosteum covering the fronto-nasal process of the maxilla. Anterior to the atrium the lateral wall is formed by the nasal bone and the upper nasal cartilage.

Remove the muco-periosteum in front of the atrium.

Observe the lateral branch of the *internal nasal nerve* and *vessels* descending in a groove on the nasal bone, and appreciate that the right and left upper nasal cartilages are extensions or wings of the septal cartilage.

With scissors, cut away the (left) inferior concha and note its curved attachment to the side wall of the nose.

Inferior Meatus. Note that a blunt probe passed from the orbital cavity down the *naso-lacrimal duct* into the inferior meatus, travels downwards and slightly backwards and laterally, and that it traverses the mucous membrane obliquely like a ureter entering the bladder. The flap *valve* (of Hasner) thus formed opens anywhere on the line between the summit of the curved attachment of the inferior concha and the floor of the nose.

Remove the muco-periosteum from the inferior meatus.

The (*bony*) *naso-lacrimal canal* opens at the summit of attachment of the inferior concha, which is at the junction of its anterior $\frac{1}{3}$ with its posterior $\frac{2}{3}$. The thinnest part of the lateral wall of the inferior meatus is situated behind the point of debouchment of the nasolacrimal canal. This thin area, triangular in shape, is formed by the maxillary process of the inferior concha (*fig. 792*). Its apex falls far short of the floor of the nose. Its center lies about $2\frac{1}{2}''$ from the tip of the nose, or $1\frac{1}{4}''$ from the anterior bony aperture. Through this triangular area the surgeon may pass a hollow needle into the maxillary sinus. With a probe break down this thin partition. Behind, it articulates with the vertical plate of the

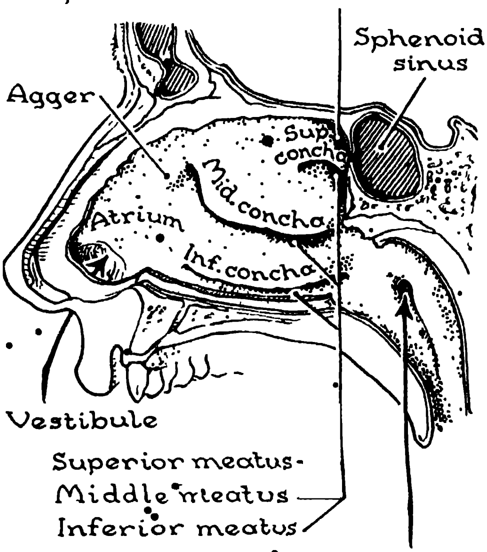


FIG. 747 The lateral wall of the nose

palatine bone; in front, with the medial wall of the maxilla, which is strong and will not give way before the probe. A sensory twig, the ***nasal branch of the anterior superior dental nerve*** with its companion artery, pierces the lateral wall abreast of the incisive foramen, but they are not likely to be seen.

With scissors, cut away the middle concha from its attachment.

Middle Meatus. Note that a curved probe passed from *the lowest part of the*

frontal sinus into the nose enters the middle meatus at the anterior end of a curved groove, the *hiatus semilunaris*. The hiatus has a sharp lower edge; above it there is an ovoid swelling, the *bulla ethmoidalis*. The anterior end of the hiatus opens by an *ostium* of variable size into the *maxillary sinus at its highest part*. An *accessory* (an acquired) *ostium* is often to be seen about half an inch behind the main (the primary) ostium. The papery lacrimal bone lies immediately behind the strong force-transmitting fronto-nasal process.

With a sharp probe break through the lacrimal bone and then open into the lacrimal sac, as the surgeon may do to afford drainage when the nasolacrimal duct is obstructed.

The orifices of several anterior ethmoidal cells are seen under cover of the middle concha. The cell (or cells) in the bulla is the *bullar* or *middle ethmoidal cell* (or cells).

Cut away the superior concha.

Superior Meatus. The large orifices of one or more posterior ethmoidal cells open here.

Spheno-ethmoidal Recess. The circular orifice of the sphenoidal air sinus opens here, high up (*fig. 749*).

Proceed to pick away, one by one, the partitions between the ethmoidal cells in order to display the thin orbital plate of the ethmoid which closes the cells laterally and at the same time forms the medial wall of the orbital cavity.

THE BLOOD SUPPLY TO THE NASAL CAVITIES. The arterial network is very free and is derived from:

(a) The *ophthalmic artery*, via its anterior and posterior ethmoidal branches, supplies the upper and front parts of the lateral wall and septum.

(b) The (*internal*) *maxillary artery*, via its spheno-palatine branches, which traverse the spheno-palatine foramen, supplies the posterior parts of the lateral wall and septum; the long spheno-palatine branch reaches the septum by crossing the roof of the cavity at the junction of the anterior and inferior aspects of the body of the sphenoid.

(c) The *facial artery*, via the superior labial artery, supplies the antero-inferior part of the septum.

The *venous network* forms a distensible cavernous tissue, especially over the inferior and middle conchae, its function being to warm and humidify the inspired air. Following the arteries, the veins drain: (a) upwards via the ethmoidal veins into the superior ophthalmic vein; one vein, however, piercing the cribriform plate, joins the veins beneath the frontal lobe of the brain; (b) backwards through the spheno-palatine foramen to the pterygoid plexus; and (c) forwards to the anterior facial vein. The drainage is chiefly via route (b).

The *lymphatics* (*p. 776*).

Perineural spaces. Around the filaments of the olfactory nerve distributed in the nasal mucosa are perineural spaces. These have been shown by experiment to be prolongations of the cranial subarachnoid space and to have no connection with lymph vessels (Faber).

THE NERVE SUPPLY (*fig. 743*). The upper parts of the septal and lateral walls (over a total area of 2 sq. cm.) are supplied by the *olfactory nerves*, which, ensheathed in their membranes, pierce the cribriform plate in twenty or so branches. These end in the olfactory bulb. One branch runs to the vomeronasal organ of Jacobson.

To cut off the sensory nerve supply: (1) Inject with a curved hollow needle an anesthetic through the spheno-palatine foramen; (2) put a plug of gauze (soaked in anesthetic) in the angle between the nasal bone and the septum; (3) and another plug of gauze under the anterior end of the inferior concha.

The 1st anesthetises the branches of the spheno-palatine ganglion of which the long and short spheno-palatine and the pharyngeal branches enter via the spheno-palatine foramen; while an inferior nasal branch enters via the vertical plate of the palatine bone (*p. 751*). The 2nd catches the internal nasal branches of the anterior ethmoidal nerve. It is the medial of these branches that grooves the nasal bone and appears on the dorsum nasi as the ext. nasal nerve. The 3rd catches the nasal branch of the anterior superior dental nerve which pierces the medial wall of the maxilla deep to the inferior concha. The branches of the *infra-orbital nerve* to the vestibule and mobile part of the septum would remain intact (*fig. 621*).

Observe again the relationship of the spheno-palatine foramen to the roof of the nose and to the middle concha.

The Paranasal Air Sinuses (sphenoidal, ethmoidal, frontal, and maxillary) are bilaterally paired, but they are commonly asymmetrical.

THE SPHENOIDAL SINUSES are two in number—a right and a left. They are variable in extent, rarely symmetrical, and the partition between them is usually deflected. They occupy the body of the sphenoid, but may extend into the basi-sphenoid, even into the basi-occipital and into the anterior and posterior clinoid processes. Pass wires along the optic canal (foramen), pterygoid canal, and foramen rotundum to represent the optic nerve, nerve of the pterygoid canal, and maxillary nerve, and note that they are commonly in contact with, and may raise ridges on, the lateral wall and floor of the sinus. Observe the relationship of the sinus to the hypophysis cerebri above, and to the cavernous sinus and carotid artery laterally.

The circular ostium of the sinus is near either the middle or upper part of the anterior wall.

THE MAXILLARY AIR SINUS (THE ANTRUM OF HIGHMORE). Between the inferior concha and the ethmoidal bulla the lateral wall of the nose is largely membranous, and a pin pushed through it will enter the sinus, but unless directed downwards there is danger that it may enter the orbit. The maxillary ostium (*fig. 749*) opens into the hiatus semilunaris, near the roof of the sinus. It is usually an oval or slit-like canal, 4.5 mm. long. Hence, when the mucous membrane lining it is congested, the canal may be obstructed temporarily. It may, however, be very large.

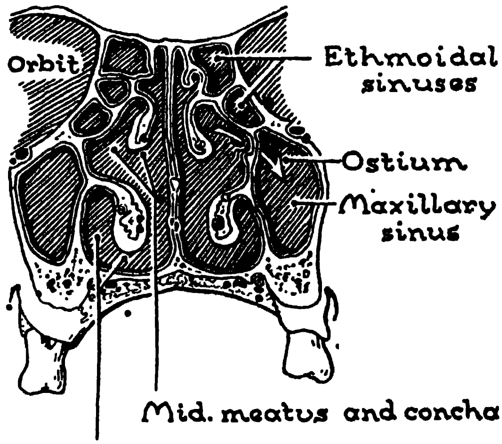


FIG. 748. The nasal cavities and adjacent air sinuses, or coronal section.

With the aid of bone forceps remove the greater part of the medial wall of this sinus.

The maxillary sinus (*fig. 748*) is a *four-sided, hollow pyramid*; the medial or nasal wall is the base; the apex stretches towards, or even into, the zygomatic bone; the walls are translucent; one facing the infratemporal fossa, one the face, and one the orbital cavity. Because the floor of the orbital cavity is concave, the roof or orbital surface of the maxillary sinus is

convex. The *infra-orbital canal* creates a ridge on the orbital and facial walls. The floor or lower border of the sinus lies below the level of the floor of the nose. From the floor one or two *septa* project upwards according as two or three molar teeth have erupted. The roots or root of any *tooth* might project into the maxillary sinus, save those of the incisors for they are embedded in the premaxilla. Those of the molars commonly do; hence, infection walls—the bone is of egg-shell thinness and there they occupy bony grooves that loop downwards and are covered on one surface with mucous membrane.

THE ETHMOIDAL SINUSES OR CELLS (*fig.* 749) may be likened to eight or ten rubber balloons placed in an oblong box and fully inflated through their stalks which project through holes in the side of the box. The result must be an oblong mass of inflated balloons, but the

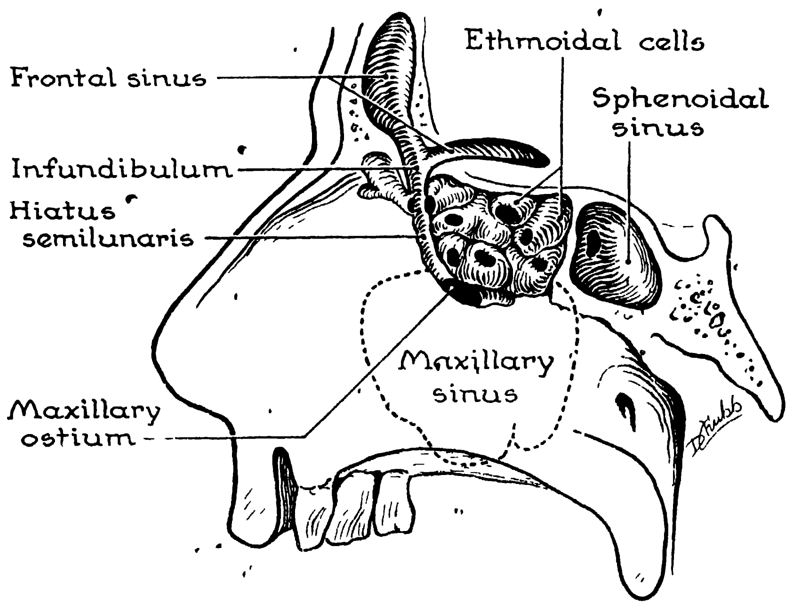


FIG. 749. Scheme of the paranasal sinuses Note that fluid in the frontal sinus would tend to flow through the infundibulum, along the hiatus, and into the maxillary sinus, because the orifice of the former sinus is at its floor and of the latter sinus at its roof. The sphenoidal ostium is in the upper half of its anterior wall. The ethmoidal ostia are variable.

may readily spread from a decaying tooth to the sinus; again, after extraction of a tooth, the empty socket may connect the sinus with the mouth.

On removing the muco-periosteal lining from the sinus, the anterior and posterior *dental vessels* and *nerves*, derived from the infra-orbital vessels and nerve, are exposed (*fig.* 742). Where there is diploe they run in bony canals, but for the most part—on the infratemporal and facial

shape of a particular balloon (or cell) depends upon the degree to which it is inflated. All air cells vary much in shape and in extent. A small air cell calls for a large adjacent cell or for several small cells. The ethmoidal cells are mainly limited by the orbital plate (lamina papyracea) of the ethmoid laterally, but the surrounding (lacrimal, frontal, sphenoid, palatine, and maxillary) bones help to close the cells.

THE FRONTAL SINUS is merely an anterior ethmoidal cell which has extended beyond the ethmoid into the vertical and orbital plates of the frontal bone. Topographically, it is frontal; developmentally, it is ethmoidal. It drains downwards. Its secretion tends to flow along the hiatus semilunaris into the maxillary sinus whose orifice is near its roof. One or more ethmoidal cells commonly extend into the orbital plate of the frontal bone and even into the lesser wing of the sphenoid.

Development. The upper and lower jaws and the other bones of the face require to enlarge progressively as the teeth erupt. Enlargement is most economically achieved by the development of hollow bone, hence, the marrow cavities in long bones and the air sinuses in skull bones.

The sinuses appear between the third and fourth foetal months as evaginations of the nasal mucosa. At birth they are shallow depressions. The *frontal sinus* begins to invade the vertical plate of the frontal bone about the eighth month, but it does not rise above the nasion until the 3rd year. Occasionally it extends but slightly into the vertical plate and extensively into the orbital plate. The *sphenoidal sinus* at the 6th year extends about $\frac{1}{4}''$ in all diameters. The *maxillary sinus* is the size of a small pea at birth; at the 6th year it is about $\frac{3}{4}''$ in all diameters.

Average Dimensions (width, height, and antero-posterior depths) in the adult are: frontal sinus, $1'' \times 1\frac{1}{4}'' \times \frac{1}{2}''$; sphenoidal sinus, $\frac{2}{3}'' \times 1'' \times 1''$; maxillary sinus, $1'' \times 1\frac{1}{3}'' \times 1\frac{1}{3}''$.

The *Mucoperiosteum* of the sinuses has a ciliated epithelium like that of the nasal cavities. Being less glandular, it is less vascular and thinner; and it is more readily detached from the bone.

Nerve Supply. The sinuses are supplied by the ophthalmic (V^1) and the maxillary (V^2) nerves—the frontal sinus via the supra-orbital nerve; the anterior ethmoidal sinuses via the anterior ethmoidal nerve; the posterior ethmoidal and sphenoidal sinuses via the posterior ethmoidal nerve and the pharyngeal and other branches of the maxillary nerve travelling through the spheno-palatine ganglion; and the maxillary sinus via the superior dental nerves.

CHAPTER 25

THE LARYNX

The larynx is the upper end of the respiratory passages. Its *superior aperture* rises freely into the pharynx and is separated on each side from the hinder part of the thyroid cartilage by a space, the *piriform fossa*, and from the back of the tongue by a depression, the *vallecula*. The valleculae of the two sides are separated by a median fold of mucous membrane, the *glosso-epiglottic fold*.

We shall build up the larynx under the following headings:

(1) *External framework* comprising: Cricoid and thyroid cartilages, and the crico-thyroid joint, ligament, and muscle.

(2) *Internal framework* comprising: (a) Arytenoid cartilage, crico-arytenoid joint, crico-vocal membrane, and vocal ligament. (b) Epiglottic cartilage, quadrangular membrane, and vestibular ligament.

(3) *Intrinsic muscles.*

(4) *Vessels and nerves.*

(5) *Mucous membrane.*

The External Framework (*fig. 753*). THE CRICOID CARTILAGE (Gk. = like a ring) has two parts: a *lamina* or signet-plate more or less quadrilateral and placed behind, and an *arch* with horizontal lower border and oblique upper border. Its lumen is circular and it can with difficulty be slipped over a finger (*fig. 750*).

It lies in front of the 6th cervical vertebra. It develops like a tracheal ring. The lamina chondrifies late and independently of the arch. It is the only complete ring in the respiratory passage.

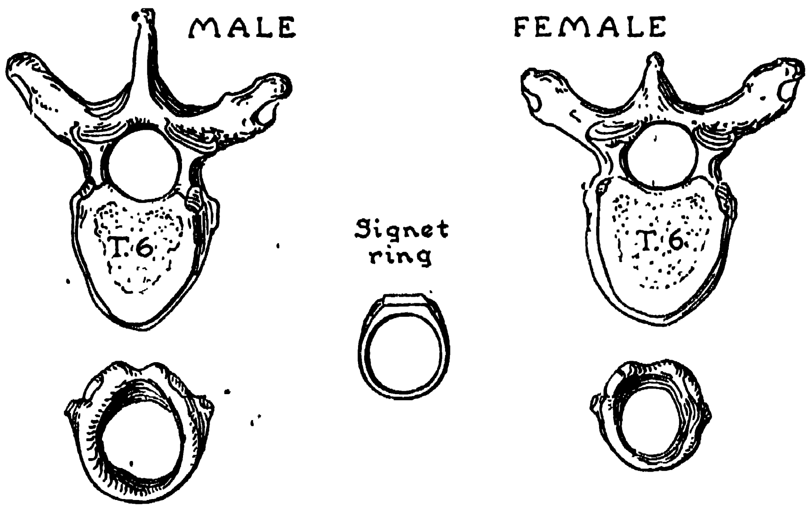


FIG. 750. Compare the lumina of a cricoid cartilage, a vertebral foramen, and a signet ring.

THE THYROID CARTILAGE (Gk. = like a shield) consists of two quadrilateral plates, the *laminae*, which converge to meet in the median plane in front at an angle. After puberty the angle varies with the sex, being like the subpubic angle —greater in the female than in the male (*fig. 751*). The upper border of each lamina is sinuous, and in the male it pro-

jects forwards beyond the anterior attached border, thereby creating a projection, the *laryngeal prominence* or Adam's apple. The *posterior border* is free, rounded and prolonged into an *upper* and a *lower horn*, the upper being the longer (*fig. 752*). The lateral surface is crossed by an *oblique line*, which extends from a tubercle near the upper border to a tubercle on the lower border, and gives attachment to 3 muscles—Sterno-thyroid, Thyro-hyoid, and Inferior Constrictor.

THE CRICO-THYROID JOINT. There is a *circular facet* on the medial aspect of the tip of the inferior horn of the thyroid cartilage for articulation with a corresponding facet on the side of the lamina of the cricoid. *Radiating fibers*, arranged in three bands, moor the lower horn of the thyroid to the cricoid and allow it to rotate up and down like the visor of a helmet, and perhaps to glide forwards slightly. This is a synovial joint. The *median crico-thyroid ligament* is a strong triangular band with truncated apex that unites adjacent borders of the cricoid and thyroid in the median plane. It acts as a restraining ligament. The *Crico-thyroid* is the rotator muscle. It arises from the outer surface of the arch of the cricoid, which it monopolizes, and it is inserted into the lower border of the lamina of the thyroid cartilage and into the anterior border of the inferior cornu. Being a detached part of the Inferior Constrictor, it is supplied by the vagus nerve, the particular branch being the external laryngeal.

The lower border of the cricoid is attached to the first tracheal ring by the *crico-tracheal membrane* (lig.). The upper border of the thyroid is attached to the upper border of the body and greater horn of the hyoid by the *thyro-hyoid membrane*, the posterior edge of which is thickened to form the *lateral thyro-hyoid ligament*. The ligament joins the tips of the respective horns of the thyroid cartilage and hyoid bone, and it contains a nodule (cartilago triticea), which during development became detached from the thyroid cartilage.

Internal Framework. The more delicate inner parts of the larynx are shielded by the thyroid cartilage.

THE ARYTENOID CARTILAGE (paired) is like the quadrant of a cone in having 3 approximately flat surfaces (medial, posterior, and inferior) and 1 convex surface (anteró-lateral). [Actually the medial surface is flat; the posterior and inferior are concave; and the antero-lateral is

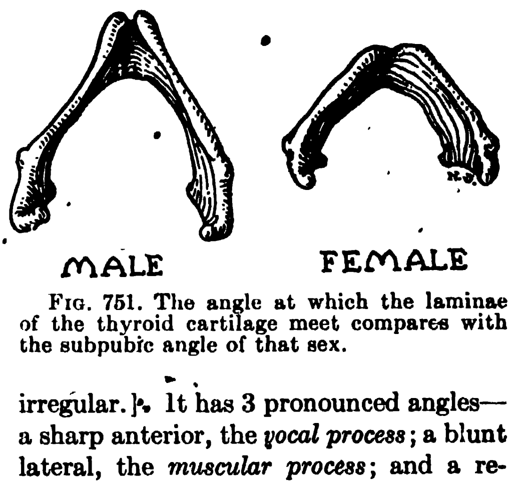


FIG. 751. The angle at which the laminae of the thyroid cartilage meet compares with the subpubic angle of that sex.

irregular.] It has 3 pronounced angles—a sharp anterior, the *vocal process*; a blunt lateral, the *muscular process*; and a recurved superior, the *apex*.

THE CRICO-ARYTENOID JOINT. The under surface of each arytenoid and the lateral sloping parts of the upper border of the lamina of the cricoid have oval articular facets; but oddly enough the long axes of the ovals are at right angles to each other. This allows the arytenoid to glide medially and laterally, forwards and backwards, and to rotate.

VOCAL LIGAMENT AND CRICO-VOCAL MEMBRANE. From the end of the vocal process a band, the *vocal ligament* (thyro-arytenoid ligament) passes horizontally

forwards to the angle between the thyroid laminae at its midpoint. It is the framework of the vocal fold (vocal cord). The triangular membrane of which it forms the upper border is called the *crico-vocal membrane* (conus elasticus). This membrane is attached below to the whole length of the upper border of the arch of the cricoid; in front it blends with the crico-thyroid ligament; and, after curving medial to the lower border of the thyroid cartilage, it ends above in a free upper border, the *vocal ligament.*

From its lateral border a sheet of fascia, the *quadrangular membrane,* similar in structure to the crico-vocal membrane, curves backwards to the lateral border of the arytenoid cartilage. The free upper edge of the quadrangular membrane is slightly thickened and called the *aryepiglottic ligament*; the free lower border is markedly thickened and called the *vestibular ligament.* It is the basis of the vestibular fold or false vocal cord.

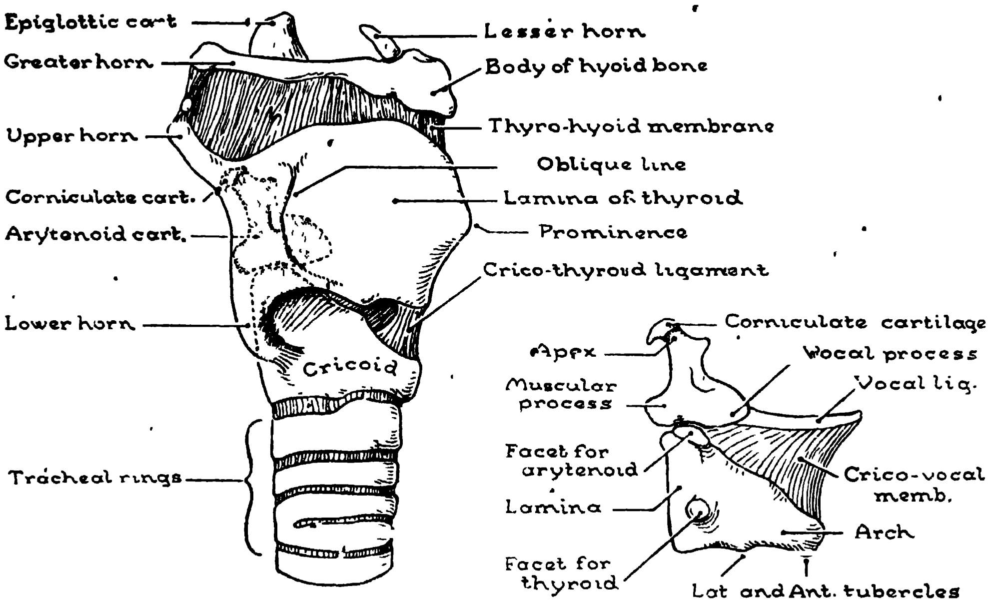


FIG. 752 The cartilages of the larynx, side view

THE CARTILAGE OF THE EPIGLOTTIS (unpaired) is a curved leaf-shaped cartilage, pitted to accommodate glands and perforated by vessels and nerves. A ligament, the *thyro-epiglottic ligament,* attaches its stalk to the angle of the thyroid laminae above the vocal ligaments. Its rounded tip rises above the level of the hyoid bone and its anterior surface is attached to the hyoid bone by a fibrous band, the *hyo-epiglottic ligament.*

The recurved cornu or apex of the arytenoid, the *corniculate cartilage,* is separated from the main cartilage by a film of perichondrium. In the hinder part of the quadrangular membrane a detached portion of the side of the epiglottic cartilage was stranded during development; like the epiglottic cartilage it is pitted by glands. It is called the *cuneiform cartilage,* but it resembles a club more than a wedge. Its lower end is fixed to the arytenoid cartilage.

Note that this internal framework of

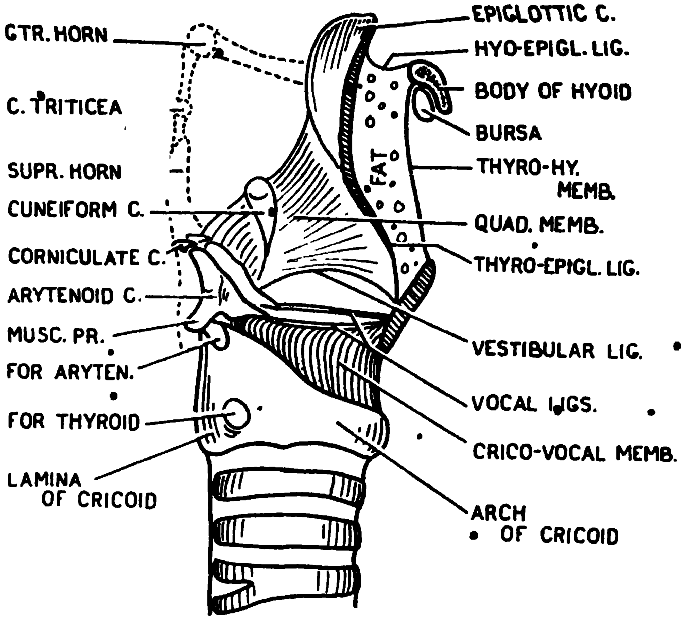


FIG. 753. The cartilaginous and membranous skeleton of the larynx. (The right half of the thyroid cartilage and the right quadrangular membrane have been removed.)

cartilage, membrane, and ligament is covered with a sheet of muscle on the outside and is lined with mucous membrane on the inside. This being so, the framework is most readily revealed by splitting the larynx and trachea from behind by a median incision and peeling off the mucous membrane.

Between the vestibular and vocal ligaments the membranous framework is thin and is ballooned laterally to form a canoe-shaped depression.

The Intrinsic Muscles (*fig. 754*) of the larynx are applied to the sides and back of the internal framework like a sphincter, imperfectly subdivided into several parts.

LATERALLY, it forms a sheet in 5 parts: (1) *The Lateral Crico-arytenoid* is applied to the crico-vocal membrane. It arises from the upper border of the arch of the cricoid; passes backwards deep to the lower border of the thyroid and is inserted into the muscular process of the arytenoid. (2) *The Thyro-arytenoid* is

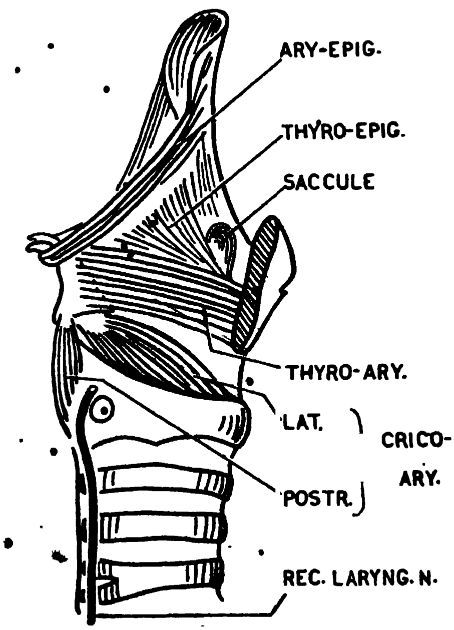


FIG. 754. The intrinsic muscles of the larynx (on side view).

the upward continuation of the Lateral Crico-arytenoid. It is applied to the

vocal and vestibular ligaments and extends above them. It arises from the lamina of the thyroid adjacent to the angle and is inserted into the lateral border of the arytenoid. (3) *The Vocalis* is the most medial of the bundles of fibers in the Thyro-arytenoid. Triangular on cross-section, it is applied to the under and lateral surfaces of the vocal ligament. It arises in the angle between the thyroid laminae, and it is inserted into the vocal process of the arytenoid cartilage and into an oblong pit lateral to it; some fibers are attached to the vocal ligament. (4) *The Thyro-epiglotticus.* Wisps of muscle fiber, lying on the quadrangular membrane above the level of the Thyro-arytenoid, pass irregularly from the thyroid cartilage to the neighborhood of the epiglottic cartilage. (5) *The Ary-epiglotticus* is applied to the upper free margin of the quadrangular membrane. It is a continuation of the Arytenoideus Obliquus described below.

POSTERIORLY, there are 2 parts: (1) *The Arytenoideus* is a thick transverse muscle that covers the arytenoid cartilages (save their apices) posteriorly. It arises from the lateral border and adjacent part of the posterior surface of one arytenoid and is inserted into the same parts of the opposite arytenoid. The *oblique fibers* arise from the muscular process, decussate with fibers arising from the muscular process of the opposite side, and are partly inserted into the apex of the opposite arytenoid and partly continued as the *Ary-epiglotticus* to or towards the epiglottic cartilage.

(2) *The Posterior Crico-arytenoid,* though the last muscle to be described, is perhaps the most important of all. Its action is to separate the vocal cords, thereby widening the rima glottidis. All other muscles have a sphincteric action and close the larynx. The Posterior Crico-arytenoids are, therefore, "*safety muscles*". Bilateral paralysis results in closure of the rima glottidis with the attendant risk of suffocation. For a similar reason we have already referred to the Genio-glossi as "*safety muscles*".

The Posterior Crico-arytenoid arises from its own half of the posterior surface of the lamina of the cricoid and is there separated from its fellow by a ridge from which the oesophagus takes origin. The upper fibers pass horizontally, the lower vertically to the muscular process of the arytenoid.

Definitions. The term "*glottis*" is sometimes applied to the vocal folds The term "*rima glottidis*" is applied to the narrow or cleft-like portion of the air passages bounded on each side by a vocal fold and the base of an arytenoid cartilage.

Muscle Actions and Uses (*figs. 755, 756*). The muscles of the larynx have three functions, (1) to open the rima glottidis, allowing entry of air so that we can breathe; (2) to close the rima glottidis and vestibule, denying entry to food when we swallow; (3) to regulate the tension of the vocal cords when we speak and cough.

The first two actions are automatic and are controlled by the medulla; the third is voluntary and is controlled by the cerebral cortex.

MUSCLES ABDUCTING AND ADDUCTING THE CORDS, that is, opening and closing the rima glottidis. The paired *Posterior Crico-arytenoids* are the only abductors. Their horizontal fibers work on a vertical axis and rotate the arytenoids laterally; their vertical fibers draw the arytenoids down the sloping facets on the upper border of the lamina of the cricoid. The Posterior muscles, therefore, abduct the cords, i.e., widen the rima glottidis.

The *Lateral Crico-arytenoids* rotate the arytenoid cartilages medially and, so,

adduct the cords. The *Arytenoideus* approximates the arytenoid cartilages.

MUSCLES CLOSING THE VESTIBULE. The rima glottidis being closed, the *Thyro-arytenoids* with the help of the *Ary-epiglottic* and *Thyro-epiglottic* muscles close the uppermost compartment or vestibule of the larynx, and tilt the arytenoid cartilages forwards, as in the act of swallowing.

DURING THE ACT OF SWALLOWING the *Ary-epiglottics* constrict the entrance to the larynx; the *Thyro-arytenoids* constrict the vestibule and tilt the arytenoid cartilages forwards so that their apices touch the tubercle of the epiglottis; the *Arytenoideus* brings the arytenoid cartilages together and the Lateral *Crico-arytenoids* swing the vocal processes medially, thereby closing the rima glottidis (see also p. 736).

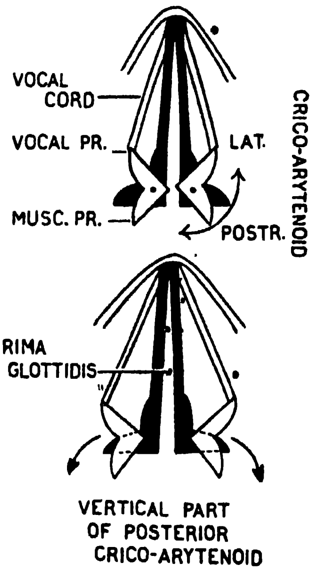


FIG. 755. Scheme of glottis from above, explaining the actions of the Lateral and Posterior Crico-Arytenoids.

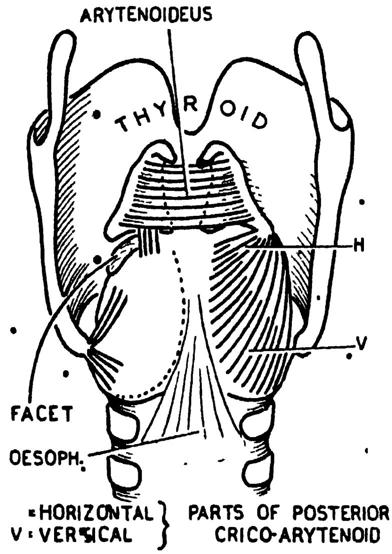


FIG. 756. Larynx from behind, showing muscles and ligaments.

MUSCLES AFFECTING THE TENSION OF THE CORDS. The cords being adducted the *Crico-thyroids* rotate the thyroid cartilage downwards and forwards, away from the arytenoid cartilages. At the same time the *Posterior Crico-arytenoids* steady (or perhaps tilt backwards) the arytenoid cartilages on the cricoid cartilage. The slackness of the cords being thus removed, the Vocales muscles are in a condition to contract effectively. The Vocales may, indeed, be regarded as controlling the fine adjustment of tension.

Nerve Supply. The nerve supply to the larynx is derived solely from the vagus via its superior and recurrent laryngeal branches. Both are mixed nerves: the superior supplying the Crico-thyroid muscle and sensation to the larynx above the vocal folds; the recurrent supplying all the internal muscles and sensation below the vocal folds:

The *recurrent laryngeal nerve* enters the larynx by passing deep to the lower border of the Inferior Constrictor and in contact with the back of the crico-thyroid

joint. There (or lower down) it divides into: an *anterior branch* which ascends on the lateral sheet of muscles and supplies them; and a *posterior branch* which supplies the two posteriorly placed muscles and anastomoses with the internal laryngeal nerve.

The *superior laryngeal nerve* divides into the internal and the external laryngeal nerve (*fig. 675*). The *internal laryngeal nerve* perforates the thyro-hyoid membrane as several branches, crosses the anterior wall of the piriform fossa, reaches the lateral sheet of muscles, and is sensory to the larynx above the glottis, and to the region immediately around the aperture of the larynx. The *external laryngeal nerve* supplies the Crico-thyroid.

Blood Supply. The *superior laryngeal branch* of the superior thyroid artery and the *inferior laryngeal branch* of the inferior thyroid artery supply the larynx. The *crico-thyroid branch* of the superior thyroid artery assists.

Lymph vessels (p. 776).

The Interior of the Larynx. The larynx extends from the tip of the epiglottis, which projects above the level of the hyoid bone, to the lower border of the cricoid cartilage.

The Superior Aperture or entrance to the larynx is oblique. It is bounded by the upper border of the epiglottis, the ary-epiglottic fold with the contained upper ends of the cuneiform and corniculate cartilages, and the mucous membrane covering the upper border of the Arytenoideus (*fig. 724*).

The Vestibular and Vocal Folds, also called the false and true vocal cords. From each side of the larynx two antero-posterior folds, the *vestibular* and the *vocal folds*, project medially into the larynx. These overlie the ligaments of the same names (*fig. 753*) and are about ·5 mm. apart. The upper or vestibular fold extends forwards from the middle of the antero-lateral surface of the arytenoid; the lower or vocal fold extends forwards from the vocal process of the arytenoid; and both folds reach the angle between the laminae of the thyroid cartilage near its mid-point. The vocal folds are visible from above because their attachments are medial to those of the vestibular folds. They form the anterior $\frac{2}{3}$ or *intermembranous part* of the rima glottidis; the medial borders of the bases of the arytenoids form its posterior $\frac{1}{3}$ or *intercartilaginous part.*

The Three Parts of the Larynx. The vestibular and vocal folds divide the cavity of the larynx into three parts. (1) In the upper part or *vestibule* of the larynx, a median swelling, the *tubercle of the epiglottis*, overlies the thyro-epiglottic ligament, and a much smaller swelling on each side overlies the cuneiform cartilage. (2) On each side of the *middle part* the canoe-shaped depression between the vestibular and vocal folds is called the laryngeal sinus (ventricle). From the anterior end of the sinus a cul-de-sac of mucous membrane, called the *laryngeal saccule* (appendix), extends upwards for about half an inch. It lies between the quadrangular membrane and the Thyro arytenoid. Occasionally, it extends above the thyroid cartilage and through the thyro-hyoid membrane. In the gorilla, the saccule is of enormous size, extending to the axilla. (3) The *inferior part* when viewed from below, is seen to be roofed over, except medianly, by the crico-vocal membranes; it is circular on cross-section.

Structure. *The Mucous Membrane* has a *stratified ciliated epithelium.* Goblet cells, mucous glands, lymph follicles, and diffuse lymphoid tissue are present, as elsewhere in the respiratory passage. *Ciliated* epithelium gives place to *non-ciliated* where vibration and impact occur,

i.e., over the *vocal folds*; and to *stratified squamous epithelium* over the upper part of the back of the epiglottis due to the friction of passing food. The mucous membrane is *adherent* over the epiglottis and vocal folds; elsewhere and especially behind, where movements are most free, it is loose. *Mucous glands* are abundant in the pits of the epiglottic and cuneiform cartilages, in the triangular pit of each and later to turn into bone, as does the hyoid bone, which also is a branchial derivative, at an earlier age. The thyroid cartilage in youth can be cut with a knife; in later life it requires to be sawn. The epiglottic and cuneiform cartilages are not derived from branchial cartilages. They are formed of elastic cartilage and, like the cartilages of the external ear and pharyngo-tympanic tube, the

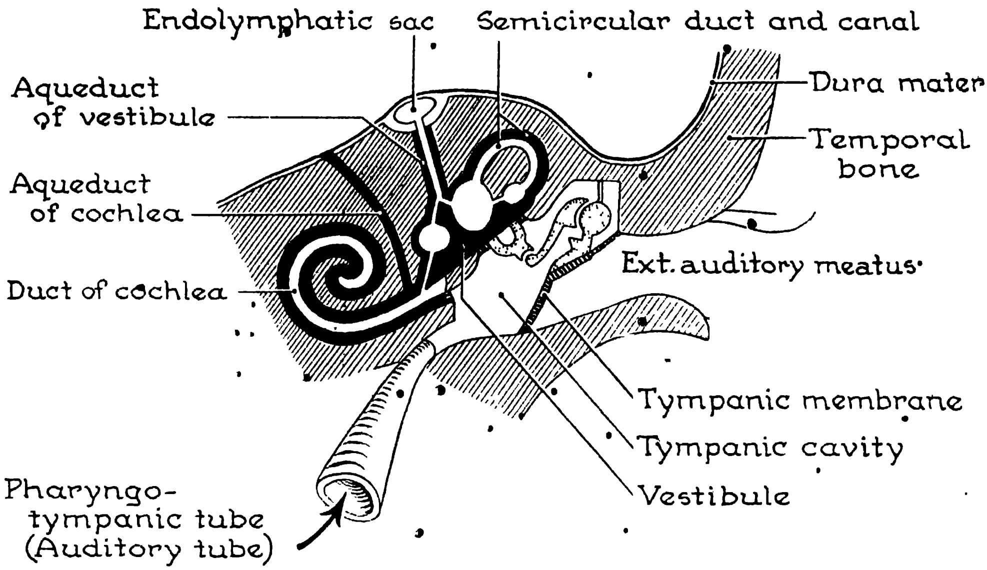


FIG. 757. General plan of the three parts of the ear.

arytenoid cartilage, about the ventricles, and in the saccule.

The Vocal Folds or *Cords* comprise the vocal ligament, the Vocalis muscle, and a covering of thick non-ciliated epithelium. They are nonvascular and therefore pale. They contain little submucous tissue and no glands and therefore they do not easily become swollen with risk of suffocation.

Types of Cartilage. The thyroid, cricoid, and arytenoid cartilages and the tracheal rings are derived from branchial cartilages and, so, are *hyaline* in type. They tend to calcify before middle life corniculate cartilages and the vocal processes of the arytenoid cartilages, they neither calcify nor ossify.

THE EAR

The ear has three distinct parts—external, middle, and internal (*fig. 757*).

The External Ear consists of an auricle and an external auditory meatus.

THE AURICLE has been described (p. 580).

THE MEATUS is an inch (24 mm.) long from the bottom of the concha (or an inch and a half from the surface of the auricle). It is closed at its fundus by the

tympanic membrane. It is oval on section; so, an oval speculum should be selected when examining the membrane.

The Lateral Third of the canal (8 mm.) is *cartilaginous,* except behind where it is completed by fibrous tissue, and it is attached by fibrous tissue to the outer edge of the *bony* meatus. The cartilage of the auricle and the cartilage of the meatus are one piece of elastic cartilage. The anterior part forms a plate with two slits in it. With the tip of a finger in the meatus, the head of your jaw can be felt through a slender intervening process of parotid gland to move when your mouth is opened. The canal is sinuous, being convex upwards and convex backwards. So, pulling the auricle upwards and backwards straightens the cartilaginous part, thereby making inspection of the drum, through a speculum, possible.

The Medial Two-thirds of the canal (16 mm.) is *bony* and is formed by the tympanic bone, except above where the squamous temporal completes it. The canal is narrowest some millimeters from the tympanic membrane. Owing to this and to the upward convexity of the canal, the lowest part of the membrane cannot be seen.

STRUCTURE. Here is found the largest piece of elastic cartilage in the body; namely, the cartilage of the auricle and external auditory meatus. The cartilaginous part of the meatus is lined with thick skin in which there are hairs, sebaceous glands, and modified sweat glands which secrete cerumen or wax—hence, boils may occur here. These may be continued for a short distance along the postero-superior part of the bony meatus. Otherwise the bony meatus is lined with thin stratified squamous epithelium which is adherent to the periosteum and to the ear drum.

VESSELS AND NERVES. *Arteries:* posterior auricular, superficial temporal, and deep auricular branch of the maxillary. *Lymph vessels:* to mastoid, parotid, and superficial cervical glands. *Sensory nerves:* auriculo-temporal and auricular branch of the vagus. The latter nerve emerges through the squamo-tympanic fissure.

The Middle Ear or Tympanum. The pharyngo-tympanic (auditory) tube and middle ear are derived from the 1st and 2nd visceral pouches, and the aditus to the tympanic antrum and the antrum itself are backward extensions of the middle ear (*fig. 758*).

During the act of swallowing the tube is opened by the Tensor Palati and air is admitted to the middle ear. By this means the atmospheric pressure is kept equal on both sides of the ear drum (p. 734).

A chain of three ossicles **passes from the tympanic membrane across the middle ear to a membrane which closes an oval window, the *fenestra vestibuli,* leading to the internal ear. By this means vibrations in the air are amplified and conducted to the internal ear.**

BONY SURROUNDINGS. The features presented by the sloping anterior surface of the petrous bone described on page 630, and of the vertical posterior surface (p. 626) should be read again. The floor of the *middle cranial fossa* (*fig. 647*) is commonly papery in thinness along a narrow band which runs from a few millimeters behind the foramen spinosum towards the suprameatal spine, which lies postero-superior to the orifice of the external auditory meatus. This narrow band can be broken through with a seeker and picked away with strong forceps. It forms a continuous roof for the tube, tympanum, aditus, and antrum and it is called the *tegmen tympani* (*fig. 758*). Just lateral to the tegmen the fingernail can detect the remains of the

petro-squamous suture which fuses during the second year.

On the *under surface of the skull* (*fig. 708*) a fissure runs from the pterygoid tubercle to the anterior border of the external auditory meatus. The projecting spine of the sphenoid divides the fissure into two halves: the antero-medial half lodges the cartilaginous part of the tube; the postero-lateral half encloses the bony part of the tube and extends to the tympanum. Pass a bristle through it and get your direction.

On the *lateral aspect of the skull* (*fig. 649*) the upper border of the zygoma is continued backwards above the external auditory meatus as the *posterior root of the zygoma*, and above the mastoid as the *supra-mastoid crest*. The position of this crest depends upon the size of the Temporal muscle. Now, it so happens that in man the Temporal muscle and the floor of the middle cranial fossa usually lie at exactly the same level; hence, a hole drilled above the supramastoid crest will enter the middle cranial fossa. The lower part of the mastoid process is rough for the aponeuroses of the Sterno-mastoid and Splenius. The upper part, called the *postauditory process* (*fig. 780 A*), is smooth and triangular; developmentally, it is a downgrowth from the squama of the temporal bone and it closes the tympanic antrum laterally, just behind the supra-meatal spine. The *suprameatal spine* lies just behind the postero-superior part of the orifice of the ext. auditory meatus.

The Tympanic Cavity bears remote resemblance to a red blood cell—in being narrow and rounded, compressed at the center, and enlarged peripherally. It is half an inch in vertical diameter; 2 mm. across at the center, 4 mm. at the floor, and 6 mm. at the roof. *The Lateral Wall* is closed by the tympanic membrane, but the cavity rises a few millimeters above the membrane, this part being the *epitympanic recess* (*fig. 760*). *The Floor* is thin and it rests upon the jugular bulb which rises higher on the right side than on the left. *The Roof* or tegmen tympani is thin and sloping, and the dura mater is adherent to it; and when broken through from above, the malleus and incus are seen rising into the epitympanic recess. *Anteriorly*, the tympanic cavity narrows to become the pharyngo-tympanic tube (auditory tube). The upper part of the tube lodges the *Tensor Tympani* which lies on a thin bony shelf, whose tympanic end is upturned to form a pulley, the

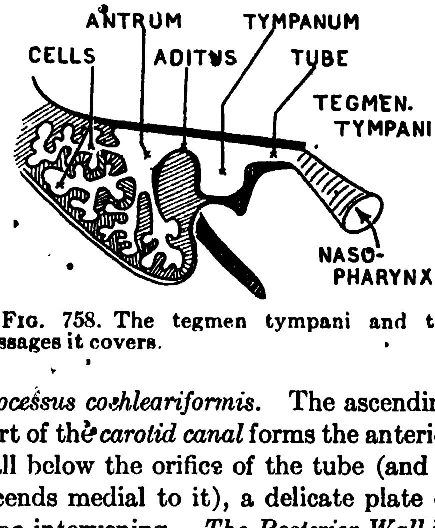


FIG. 758. The tegmen tympani and the passages it covers.

processus cochleariformis. The ascending part of the *carotid canal* forms the anterior wall below the orifice of the tube (and it ascends medial to it), a delicate plate of bone intervening. *The Posterior Wall* in its uppermost part has a tunnel, the *aditus*, through which the epitympanic recess communicates with the tympanic antrum. The aditus has the tegmen for its roof, is a few mm. long, and scarcely admits a quill. Below this, the *facial nerve* descends in the posterior wall; and jutting forwards from this wall is a minute elevation, the *pyramid*. At the apex of the pyramid there is a pinpoint orifice through which the Stapedius passes forwards to the neck of the stapes. *The Medial Wall* (*fig. 759*) has at its center a

swelling, the *promontory*, which overlies the first coil of the cochlea. On an oblique line between the promontory and the roof of the aditus are—(a) the fenestra vestibuli, (b) the canal for the facial nerve, and (c) the lateral semicircular canal. The *fenestra vestibuli* is an oval window opening into the vestibule. It is 3 mm. in the horizontal axis and it is closed by the foot-plate of the stapes. The *canal for the facial nerve* curves backwards on the medial wall (between the oval window and pyramid below and the lateral semicircular canal above) and descends within the posterior wall. The

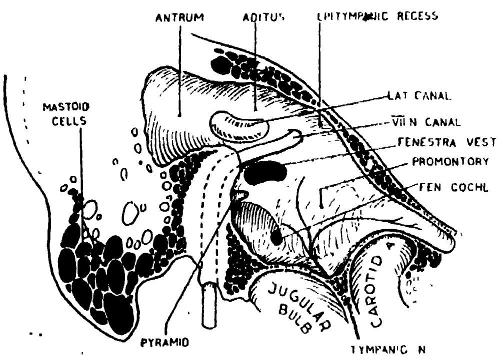


FIG 759. The medial wall of the tympanum.

wall of the canal may be dehiscent in its curved part. The *lateral semicircular canal* lies horizontally within the aditus and extends forwards above the fenestra vestibuli. The bone over it is raised and smooth. The *fenestra cochleae* is a round window opening into the scala tympani of the cochlea, and closed by the secondary tympanic membrane. It lies postero-inferior to the promontory, but it is not evident, since it lies at the end of a depression that faces backwards.

THE TYMPANIC MEMBRANE or ear drum is nearly circular, being 9 mm. high and 8 mm. wide. Set in the sulcus of the tympanic bone, it faces laterally, forwards, and downwards as though to catch sounds reflected from the ground as one advances. It is composed of circular and radial fibers and is lined with epidermis laterally and mucous membrane medially, and the handle of the malleus is incorporated in it. In fact, the radial fibers of the membrane radiate everywhere from the handle except over a triangular area, the *membrana flaccida*, between the upper end of the handle (short process) and the roof of the meatus. At the lower end of the handle the membrane is indrawn: this point, called the *umbo*, lies below the center of the membrane. The chorda tympani crosses the part of the membrane medial to the handle of the malleus.

THE AUDITORY OSSICLES (*fig. 760*). There are three ossicles—the malleus (hammer), incus (anvil), and stapes (stirrup). *The Malleus* is 8 mm. long. It has a round head with a facet posteriorly, which ends below in a cog; a long handle embedded in the membrane and ending above in a short process, which is short and conical; and an anterior process which is very slender and extends from the neck of the malleus to the squamo-tympanic fissure. *The Incus* is shaped like a molar tooth. It has a body (i.e., the crown), two diverging processes (i.e., roots), a short horizontal one and a long vertical one. The body articulates with the head of the malleus; the long process is parallel to the handle of the malleus and from its end a (lentiform) nodule projects medially to articulate with the stapes. *The Stapes* has a head with a concave socket for the incus; a short neck; anterior and posterior limbs, which are attached to an oval foot plate. The foot plate is attached by an annular ligament to the margin of the fenestra vestibuli.

JOINTS. The joints between the malleus and incus, and the incus and stapes have synovial cavities. The head of the malleus and the body and short

process of the incus lie within the epitympanic recess. A ligament suspends the head of the malleus from the roof of the cavity, another suspends the body of the incus. Ligaments attach the anterior process of the malleus and the short process of the incus to the front and back of the cavity; and around this axis the ossicles move. When the vibrating tympanic membrane moves medially, the handle of the malleus moves too and with it the incus, forced by the cog. The stapes is driven into the perilymph, which, being incompressible, causes the secondary tympanic membrane closing the fenestra cochleae to bulge.

When the tympanic membrane is forced laterally (e.g., when holding the nostrils and inflating the middle ear) the malleus moves also, the cog disengages and the incus is released. By this device the stapes is not torn from the window.

Muscles. *The Tensor Tympani* is about 2 cm. long. As its tendon leaves its canal (p. 769) it turns laterally round the processus cochleariformis to the upper end of the handle of the malleus; this it pulls medially thereby rendering the membrane tense. It is supplied by nerve V^3 through the otic ganglion.

The Stapedius occupies the hollow pyramid and is but a few millimeters long. Its tendon, on leaving the foramen at the apex of the pyramid, passes forwards to the neck of the stapes, and on contracting it pulls the anterior end of the footplate laterally. It is supplied by the facial nerve. Hence, contraction of the Tensor and Stapedius brings the movable parts of the lateral and medial walls closer together.

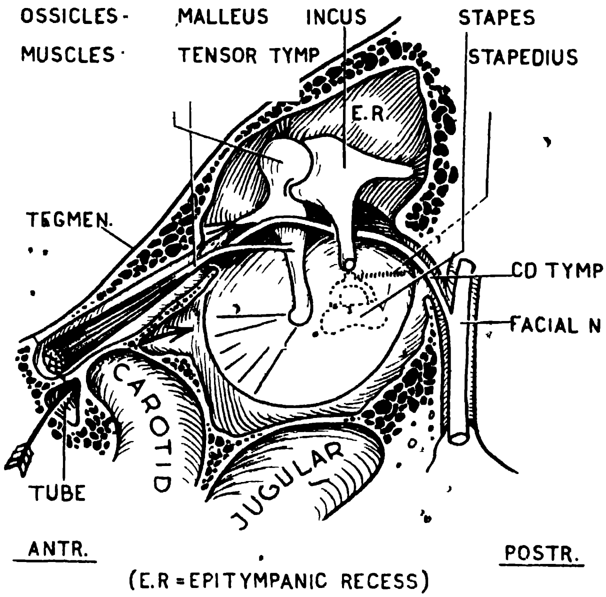


FIG. 760. The lateral wall of the tympanum and the ossicles.

The Epithelial Lining is squamous; there are no mucous glands; the "mucous membrane" closes the hole in the stapes and covers the ossicles, ligaments, and tendons forming many folds and pockets, especially in the epitympanic recess. Pus may collect in them. In the tube, how-

ever, the lining is in part ciliated and it contains goblet cells and mucous glands—particularly towards the pharyngeal end. Hence, mucus escaping from a perforated ear drum must have had its origin in the tube.

VESSELS AND NERVES *Tympanic Membrane:* The two surfaces of the membrane are supplied by different nerves and by different arteries. (a) Lateral surface—auricular br. of vagus and auriculotemporal nerve; deep auricular br. of internal maxillary artery. (b) Medial surface—tympanic br. of glossopharyngeal nerve; tympanic br. of internal maxillary artery and the stylo-mastoid artery.

The Tympanum, Tympanic Antrum, and *Mastoid Air Cells* are supplied by the tympanic nerve (*fig. 759*) which ascends through the minute canal between the jugular foramen and the carotid canal and ramifies on the promontory, which it grooves and where it is joined by two carotico-tympanic twigs of the internal carotid plexus. It supplies the *tube* also.

The arterial supply is (a) the tympanic br. of the internal maxillary artery which enters through the squamotympanic fissure, (b) the tympanic br. of the ascending pharyngeal artery which follows the tympanic nerve, (c) carotico-tympanic twigs of the internal carotid artery, which pierce the wall of the carotid canal, (d) the stylomastoid br. of the posterior auricular artery, and (e) petrosal brs. of the middle meningeal artery.

Veins pass to the pterygoid plexus and superior petrosal sinus.

Lymph vessels pass to the parotid and retro-pharyngeal glands.

The Tympanic or Mastoid Antrum. The antrum is slightly smaller than the tympanum of which it is a backward extension through the aditus into the petromastoid. It occupies the diploic layer at the expense of bone marrow. Its roof, the *tegmen tympani,* which is thin, separates it from the middle cranial fossa. The *sigmoid sinus* is very close behind it, separated by some diploe and a semicylindrical plate of bone, which is part of the inner table of the skull. The *lateral wall,* though described as part of the mastoid, is in reality a downward extension of the squama temporalis. It is about 1 mm. thick at birth and it increases by about 1 mm. a year until it is about 15 mm. thick. The antrum is large *at birth,* but there are no mastoid air cells and there is no mastoid process. The cells begin to sprout from the antrum soon after birth and grow like racemose glands, but they are not fully developed till puberty. The cells may be few and small and the mastoid relatively solid, or many and inflated and the mastoid "pneumatic". They may rupture into the groove for the Digastric. They may invade the squama and the roof of the tympanum. In addition to these *mastoid air cells* there is another collection of air cells, the *tubal* or *tympanic cells.* These sprout from the medial wall of the tympanum near the orifice of the pharyngo-tympanic tube and, like the branches of a tree, twine themselves around the carotid canal reaching towards, or even to, the apex of the petrous bone.

The Internal Ear. The internal ear is concerned with the reception of sound and with balancing. It lies within the petrous bone and has two parts, (a) the *bony labyrinth,* which contains (b) the *membranous labyrinth.*

THE BONY LABYRINTH (*fig. 761*) has three parts—*cochlea, vestibule,* and *semicircular canals.* The cochlea lies deep to the promontory, the vestibule to the fenestra vestibuli, and the lateral semicircular canal to the aditus. The whole apparatus is but 17 mm. long.

The Cochlea resembles a snail's shell with two and a half coils. It has a central pillar, the *modiolus*, whose base lies at the bottom of the internal auditory meatus; and from it an *osseous spiral lamina*, like the thread of a screw-nail, projects half way across the canal of the cochlea and, with the *basilar membrane*, which stretches across the other half, it divides the canal into two (a): the *scala vestibuli*, which opens in to the vestibule, and (b) the *scala tympani*, which is separated from the tympanic cavity, at the fenestra cochleae, by the *secondary tympanic membrane*. The two scalae are continuous at the apex of the cochlea, called the *helicotrema*. A minute duct, the *aqueduct of the cochlea*, runs from the scala tympani through the petrous bone to the notch at the margin of the jugular foramen straight below the internal auditory meatus. The aqueduct brings the perilymph within the bony labyrinth and the cerebro-spinal fluid within the subarachnoid space into communication.

The Vestibule communicates *in front* with the cochlea; *behind* with the three semicircular canals; and *medially* with the posterior cranial fossa through the aqueduct of the vestibule (*fig. 757*). When the stapes is removed, the vestibule communicates through the fenestra vestibuli (oval window) with the tympanic cavity.

The Semicircular Canals, named superior, posterior, and lateral, are set at right angles to each other and occupy three planes in space. The lateral canals of opposite sides are parallel to each other, and the superior of one side with the posterior of the other; but they vary somewhat from specimen to specimen. They are from 12 mm. to 22 mm. long, the lateral being the shortest. Each is less than 1 mm. in diameter, except at one end where there is a swelling the *ampulla*. They communicate by both ends with the vestibule. There are, however, but five openings, the superior and posterior canals having a *crus commune*.

The *superior canal* lies at a right angle with the posterior surface of the petrous bone and produces the arcuate eminence (*fig.* 647). The *posterior canal* is immediately deep to the posterior surface of the petrous bone and is parallel to it. It comes to within a third of an inch of the sigmoid sinus. The *lateral canal* is deep to the medial wall of the aditus and it runs above the canal for the facial nerve.

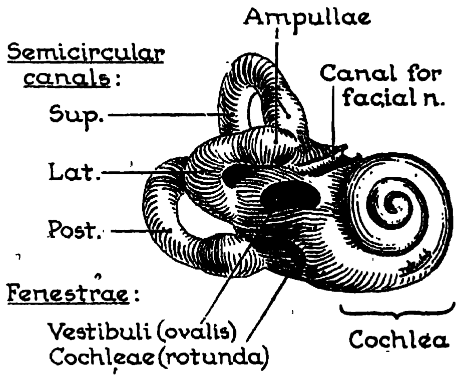


FIG. 761. The bony labyrinth.

THE MEMBRANOUS LABYRINTH comprises (a) the cochlear duct, (b) the saccule, and utricle, and (c) the three semicircular ducts. It is a closed system containing endolymph. A stalk, the *ductus endolymphaticus*, passes from the saccule and utricle through a canal (aqueduct of the vestibule) in the petrous bone to the fissure half an inch lateral to the internal auditory meatus. There the duct, a "safety" expansion sac, is placed extradurally. The *cochlear duct* lies on the vestibular side of the basilar membrane. It is triangular on section and has a blind end. The *saccule* and *utricle* occupy the vestibule. The *semicircular ducts* only partially fill their canals.

VESSELS AND NERVES pass through the internal auditory meatus. The *internal auditory artery* is a branch of the posterior inferior cerebellar a. The internal auditory vein passes to the inferior petrosal sinus. The cochlear branch of the *auditory nerve* is auditory; the vestibular branch, distributed to the utricle, saccule, and semicircular canals, is for equilibrium.

Facial Nerve, *Intrapetrous Portion.* In the internal auditory meatus, the facial nerve lies in a groove on the auditory

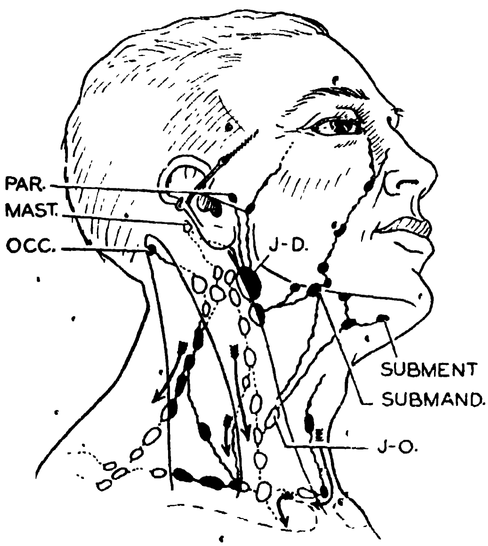


FIG. 762. The lymphatics of the head and neck. (After Rouvière.)

nerve and is there joined by its sensory root (pars intermedia), which enters the meatus with it. At the bottom of the meatus, the nerve enters the facial canal and travels through it to the stylo-mastoid foramen. Its course takes it laterally, above the vestibule of the bony labyrinth (*fig. 761*), to the medial wall of the tympanum. There it makes an abrupt bend, the *genu*. It then arches backwards and downwards above the fenestra vesbituli on the medial wall and finally descends in the bony posterior wall of the tympanum. At the genu lies the *ganglion of the facial nerve* (geniculate ganglion) and there the *greater superficial petrosal* and a *root of the lesser superficial petrosal* leave it and *sympathetic twigs* (external petrosal nerve) join it. In its descending part it supplies the *Stapedius* and gives off the *chorda tympani.*

The Facial Ganglion is chiefly, if not entirely, the cell station of the taste fibers in the greater superficial petrosal and chorda tympani nerves (*fig. 744*).

The Chorda Tympani Nerve is distributed with the lingual nerve; so, it leaves the facial nerve a few millimeters above the stylo-mastoid foramen, passes forward between the mucous and fibrous layers of the tympanic membrane, crossing the handle of the malleus, and emerges through the medical end of the petro-tympanic fissure. It then crosses medial to the spine of the sphenoid and joins the lingual nerve some distance below on the surface of the Medial Pterygoid (*figs. 678, 696, 760*).

THE LYMPHATICS OF THE HEAD AND NECK

The Main Chain of Glands of the head and neck, called the *deep cervical glands,* extends along the internal jugular vein from the base of the skull above to the clavicle below (*fig. 762*). Here it forms a *jugular lymph trunk,* which either opens independently into the angle between the jugular and subclavian veins or else joins the thoracic duct on the left side (the right lymph duct on the right). Though the deep cervical glands are largely covered by the obliquely set Sterno-mastoid, a few of them spread forwards into the upper part of the anterior triangle and many spread backwards beyond the posterior border of the Sterno-mastoid into the posterior triangle. All these glands lie superficial to the prevertebral

fascia, which serves to separate them from the prevertebral muscles, and the roots of the cervical and brachial plexuses. The inferior belly of the Omohyoid subdivides them into an upper and a lower group. A few glands of the *upper group*, which extend medially behind the naso-pharynx, are called the *retro-pharyngeal glands*. Their afferents come from the naso-pharynx and soft palate, middle ear and pharyngo-tympanic tube. Two glands are specially to be noted, (a) the *jugulo-digastric gland*, which lies below the posterior belly of the Digastric where the common facial vein enters the internal jugular; and (b) the *jugulo-omohyoid*, which lies above the posterior belly of the Omohyoid where it crosses the internal jugular. The accessory nerve is surrounded by glands both where it enters the Sterno-mastoid and where it leaves it. The upper group of glands drains into the lower group. The *lower group* (supraclavicular glands) communicates with the glands of the axilla and with the lymph vessels of the mamma. All parts of the head and neck drain through the deep cervical chain. The chain has a few forward outposts in the neck, e.g., *infrahyoid* (on the thyro-hyoid membrane) whose afferents follow the superior laryngeal artery and come from the larynx above the vocal cords; *pre-laryngeal* (on the crico-thyroid ligament) and *paratracheal* (in the groove between the trachea and oesophagus) follow the inferior thyroid artery. These receive afferents from the larynx below the vocal cords and from the thyroid gland and adjacent parts.

A Horizontal Series of superficial glands surrounds the junction of head and neck. These glands are placed on the stems of named blood vessels and they receive afferents from corresponding territories: one or two *occipital glands* lie on the Trapezius where pierced by the occipital artery, an inch infero-lateral to the inion. Their afferents are from the scalp: their efferents pass deep to the posterior border of the Sterno-mastoid. They are palpable in German Measles. One or two *mastoid glands* (post-auricular gg.) lie on the mastoid with the posterior auricular artery. Their afferents come from the scalp and auricle: efferents pass to the deep cervical glands. Several *superficial parotid glands* (pre-auricular gg) lie superficial to the parotid fascia near the superficial temporal and transverse facial arteries. Their afferents come from the scalp, auricle, eyelids and cheek. Their efferents pass to the deep parotid and superficial cervical glands. [The *deep parotid glands* may conveniently be described now. They are embeded in the parotid salivary gland. They receive afferents from the superficial parotid glands and from the external auditory meatus, tympanum, deep parts of the cheek, soft palate and posterior part of the nasal cavity. Their efferents pass to the deep cervical glands.] *The superficial cervical glands* are small and are placed beside the external jugular vein on the upper part of the Sterno-mastoid. They are an offshoot of the superficial parotid glands. Half a dozen *submandibular glands* lie on the surface of the submandibular salivary gland and also between it and the lower jaw, beside the facial artery. It has two extensions: (1) upwards in the face along the course of the facial artery; the *facial glands* are small and inconstant, except one or two at the lower border of the jaw: (2) forwards along the submental artery; the *submental glands* lie on the Mylo-hyoid below the symphysis menti. They receive afferents from the lower lip and chin and also from the tip of the tongue by vessels that pierce the Mylohyoid in

company with anastomotic branches of the sublingual artery. Its efferents pass to the submandibular glands and also to the jugulo-omohyoid gland. The *submandibular glands* receive afferents from its two extensions, and from the face, cheek, nose, upper lip, gums and tongue. Its efferents pass to the upper deep cervical glands. To examine these glands the subject should be told to drop his chin in order to slacken the cervical fascia. One index finger should then be placed below the tongue, and the fingers of the other hand should be placed below the jaw and the structures between them palpated.

The Lymph Vessels of the Tongue pass ultimately to the deep cervical glands between the levels of the jugulo-digastric and jugulo-omohyoid. Those from the *tip* pierce the Mylo-hyoid and are largely intercepted by the submental glands. Those from the submucous plexus of the *anterior two-thirds* in part spread laterally, pierce the Mylo-hyoid and end in the submandibular glands; but they also imitate the branches of the lingual and hypoglossal nerves in passing through the substance of the tongue in vertical planes; the deepest lying in the median septum, anastomose with those of the opposite side. These vessels pass to the deep cervical glands. The vessels from the *posterior third* imitate the glosso-pharyngeal nerve in running submucously. They pierce the lateral wall of the pharynx below the tonsil and run to the upper deep cervical glands.

The Lymph Vessels of the Tonsil pierce or run below the S. Constrictor mainly to the jugulo-digastric gland.

The Lymph Vessels of the Upper Teeth pass through the infraorbital foramen and run with facial artery to the submandibular glands: those from the *lower teeth* run through the mandibular canal to the deep cervical glands. The vessels from the buccal surfaces of the *upper and lower gums* run to the submandibular glands; those from the lingual part of the lower gum end in the submandibular and deep cervical glands; those from the palatal part of the upper gums accompany the vessels of the palate to the deep cervical or retro-pharyngeal glands.

The Lymph Vessels of the Larynx *above* the vocal cords follow the superior laryngeal artery through the thyro-hyoid membrane to the upper deep cervical glands after partial interception by the infrahyoid glands: those *below* pierce the crico-thyroid ligament and crico-tracheal membrane and pass to the deep cervical glands after partial interception by the prelaryngeal and paratracheal glands. Vessels of the upper and lower parts of the larynx anastomose submucously in the posterior wall of the larynx but not in the region of the cords, which act as a barrier, comparable to the one erected at the pyloric sphincter.

The Lymph Vessels of the Ear. Those of the auricle and external meatus pass to the mastoid, upper cervical and parotid glands: those of the tympanic membrane and lateral wall of the tympanum pass to the parotid glands: those of the pharyngo-tympanic tube and medial wall of the tympanum pass to the retro-pharyngeal and deep cervical glands.

The Lymph Vessels of the Nasal Cavity from the anterior part run with those of the external nose to the submandibular glands: those from the posterior pass to the retro-pharyngeal, deep parotid and deep cervical glands.

SECTION VIII

MISCELLANEOUS

CHAPTER 26

THE AUTONOMIC NERVOUS SYSTEM

This system of peripheral nerves distributes outgoing or efferent impulses to the heart, unstriped muscle wherever situated (e.g., viscera, blood vessels, skin, eye) and glands; and, it collects incoming afferent impulses from the viscera. It has two parts:

1. The sympathetic system.
2. The parasympathetic system: (a) cranial portion, and (b) pelvic portion.

The Sympathetic System. The *sympathetic system* has central connections with the thoracico-lumbar part of the spinal cord from the first thoracic to second (or third) lumbar segments inclusive (i.e., the first eight and the last eight spinal segments are excluded). The *parasympathetic system* has central connections with the brain through cranial nerves III, VII, IX, and X, and with the sacral part of the spinal cord at its (second), third, and fourth segments.

In the sense that the right and left ropes of the rudder of a rowing boat are antagonistic and yet complementary to each other, so in general are the influences of the sympathetic and parasympathetic systems. Their opposing influences maintain a balance. Their function is to regulate activities at a subconscious level. For example, efferent sympathetic impulses cause the pupil to dilate, the heart beat to accelerate, the walls of hollow organs to relax and their sphincters to contract and, therefore, to retain their contents: efferent parasympathetic impulses have the opposite effects—the pupil contracts, the heart beat slows, the walls of hollow organs contract and their sphincters relax and, therefore, expel their contents. Parasympathetic fibers do not extend to the limbs or to cutaneous structures. Stimulation of the sympathetic system causes constriction of the cutaneous and splanchnic arteries. Dogs from which the sympathetic system has been removed can continue to live provided their lives are sheltered.

Histological Structure. In so far as the *voluntary nervous system* is concerned, it is well known that the anterior and posterior columns (horns) of gray matter extend through every segment of the spinal cord; that the cells in the anterior column are *efferent* (motor) and supply the voluntary muscles through axons that make their exit via the anterior nerve roots; that the *afferent* (sensory) nerves from the skin, muscles, tendons, and joints have their cell stations in the posterior root ganglia and send their central axons via the posterior nerve roots to end partly in the posterior horns where they arborize around *connector cells*; and, that the connector cells bring them into connection with the cells in the anterior horn, thereby establishing a simple reflex arc.

In the *sympathetic system* neurones corresponding to the efferent, connector, and afferent neurones of the voluntary system are to be found (*fig. 763*). The

equivalent of the efferent or anterior horn cells, called *excitor cells,* occur (a) in the ganglia of the *sympathetic chain* (b) in the sympathetic *visceral ganglia* (cardiac, celiac, intermesenteric, hypogastric and subsidiary ganglia) which are but detached parts of sympathetic trunk ganglia, and (c) in the medulla of the *adrenal gland.* The gray matter of the spinal cord from segments Th. 1–L. 3 possesses an intermedio-lateral column (horn), and it is in this intermedio-lateral column that the sympathetic *con-*

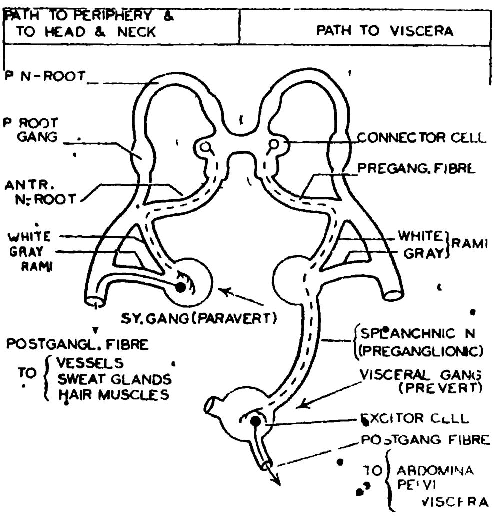


Fig. 763. General plan of a sympathetic ganglion.

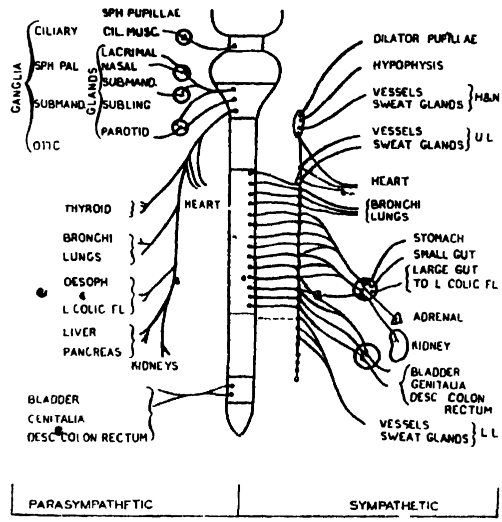


Fig. 764. General plan of the autonomic nervous system. (After Stopford.)

nector cells are lodged (*fig. 764*). Their axons pass as fine, medullated *preganglionic fibers* (2.6μ) via the anterior nerve roots and white rami communicantes (Th. 1–L. 3) to the *ganglia* of the sympathetic chain, and there form synapses with the excitor cells. Some preganglionic fibers, however, ascend and descend in the sympathetic trunk to form synapses with excitor cells in ganglia at other levels. The thoracic and lumbar *splanchnic nerves* are elongated white rami communicantes containing preganglionic fibers that pass without interruption through the ganglia of the sympathetic trunk (Th. 6–L. 3) to form synapses with excitor cells in the sympathetic visceral ganglia.

The greater (Th. 6–10), lesser (Th. 10–11), and smallest (Th. 12) thoracic splanchnic nerves and the upper lumbar splanchnic nerves end in the celiac and preaortic ganglia, whence they are relayed almost entirely as perivascular branches to the abdominal and pelvic viscera.

The adrenal gland is peculiar: branches of the lesser splanchnic nerve and upper lumbar splanchnics pass uninterruptedly through the celiac ganglion to synapse with cells of the adrenal medulla which are developmentally postganglionic cells.

The *postganglionic fibers,* or axons of the excitor cells, are mostly nonmedullated and therefore gray: (a) One or more bundles of these gray fibers called *gray rami communicantes* pass from the ganglia of the sympathetic trunk to each and every spinal nerve and so reach the blood vessels, sweat and sebaceous glands, arrectores pilorum and dartos muscles: (b) the others are *visceral fibers.* Fibers

from the *superior cervical sympathetic ganglion* pass to the cranial nerves and to the great vessels of the head and neck and so reach the various glands, the involuntary muscles of the eye, and also the heart (*fig. 765*): those from the upper *thoracic sympathetic ganglia* (Th. 1–5) pass to the thoracic viscera (heart, lung, oesophagus and aorta). The visceral fibers for the abdominal and pelvic organs, as mentioned above, are post-ganglionic fibers of the *sympathetic visceral ganglia* that have been relayed by the splanchnic nerves.

The *visceral afferent* (sensory) fibers of the sympathetic system mostly have thick medullated coats and travel with the finely medullated and non-medullated visceral efferent fibers. They pass via the white rami communicantes to the posterior root ganglia where, like the afferent fibers of the voluntary system, they have their cell stations. They enter the spinal cord by the posterior roots mainly of Th. 1–L. 3), but also of the cervical and sacral segments, and synapse with the connector cells in the intermediolateral column of gray matter. Many, however, first ascend or descend in the sympathetic trunk.

THE SYMPATHETIC TRUNK ITSELF is composed of ascending and descending fibers some of which are preganglionic efferent, postganglionic efferent, and afferent fibers. Interganglionic association fibers are believed not to occur. The ganglia of the trunk are formed by synapses between preganglionic efferent neurones and the cell bodies of postganglionic efferent neurones. Preganglionic neurones are much less numerous than postganglionic neurones and, therefore, must form synapses with a number of postganglionic neurones,—generally over five or more segments.

CEREBRAL CONTROL over the autonomic system is exercised by centers in the hypothalamic region, which lies towards the lower and front part of the third ventricle. From here descending tracts influence the connector cells.

THE AUTONOMIC SUPPLY OF INDIVIDUAL REGIONS AND ORGANS will be considered by diagram and comment. The figures indicate for the different regions and organs (a) the probable segmental locations of the connector cells

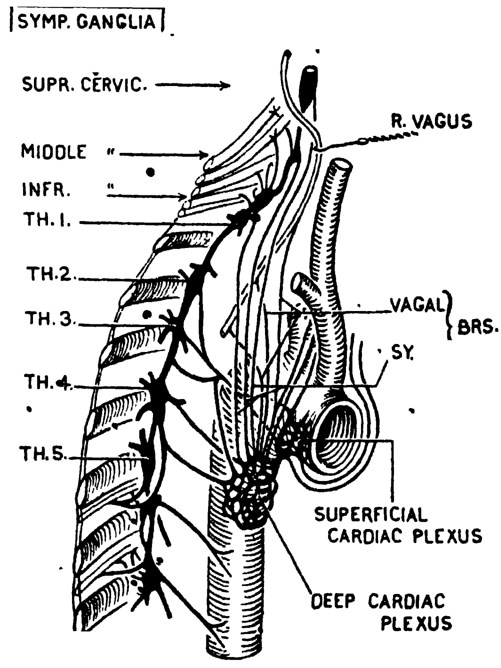


FIG. 765. Cardiac plexuses. (From White, after Kuntz and Morehouse.)

in the intermedio-lateral column of gray matter and the course of their preganglionic fibers in the anterior nerve roots and white rami communicantes; (b) the ganglia in which they synapse with effector cells; and (c) the ultimate distribution of the postganglionic fibers. The courses of the postganglionic fibers are described elsewhere.

The connector cells for the *head and neck* are situated mainly in segments Th. 1 and 2 of the spinal cord, some however

extend lower; those for the *thoracic viscera* are mainly in Th. 3 and 4; those for the *upper limb* in Th. 2-9; and, those for the *lower limb* in Th. 10-L. 3. The connector cells for the *abdominal* and *pelvic viscera*

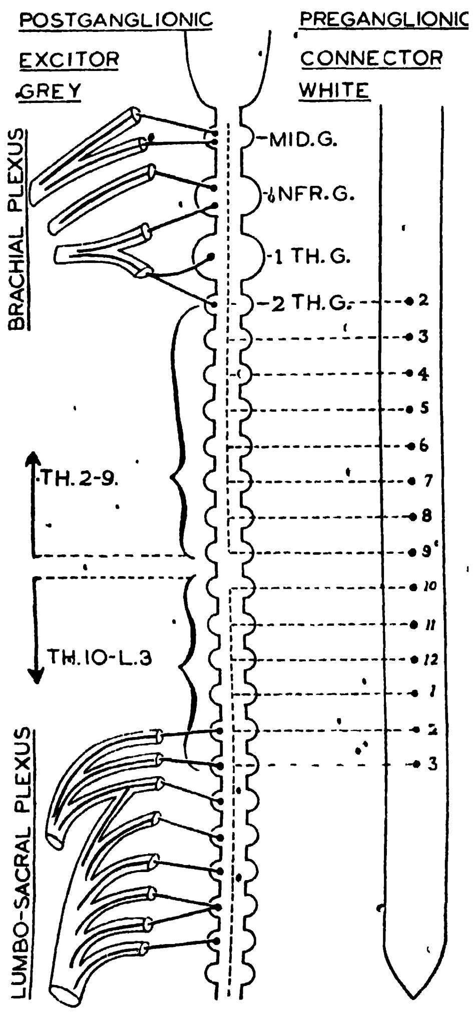


FIG. 766. The sympathetic supply to the upper and lower limbs.

are in segments Th. 6-L. 3. The visceral afferent fibers return via white rami and posterior nerve roots probably mostly to the segments from which the outgoing preganglionic fibers arise. The afferent fibers of the limbs, both superficial (cutaneous) and deep (e.g., from bones, joints, muscles, vessels) like the visceral afferent fibers, have their cell stations in the posterior root ganglia, and they enter the cord via the posterior nerve roots.

Upper Limb (*fig. 766*). Preganglionic fibers ascend in the sympathetic trunk from segments Th. 2-9 to the middle and inferior cervical ganglia and to ganglia Th. 1, 2. Thence, a dozen or so postganglionic gray rami pass to the nerves of the brachial plexus and are distributed with the branches of the plexus to the limb. The gray ramus from ganglion Th. 2 (Kuntz's nerve) to nerve Th. 1 must not be overlooked in operations intended to denervate the vessels of the upper limb: some gray rami ascend with the vertebral artery to join nerves C. 5 and 6 in the foramina transversaria. Gray rami pass directly to supply the subclavian artery, and extend along it as far as the axillary artery (*fig. 680*).

Lower Limb. Preganglionic fibers from segments Th. 10-L. 3 descend in the sympathetic trunk to ganglia L. 2-S. 3. Thence, as postganglionic fibers (gray rami) they pass to the nerves of the lumbar and sacral plexuses. The upper part of the femoral artery is supplied by an extension from the aortic plexuses along the common and external iliac arteries.

Head and Neck. The excitor cells are situated mostly in the superior cervical ganglion. They send postganglionic fibers to the sweat, salivary, lacrimal and pituitary glands, to the dilatator pupillae and the palpebral muscles (of Muller), and to the blood vessels including the carotid sinus. The thyroid gland receives branches from the middle and perhaps from all three cervical ganglia.

Thoracic Viscera. Cardiac branches pass from all three cervical ganglia and from the upper five thoracic ganglia to

the heart. Pulmonary branches proceed from ganglia Th. 2, 3 and 4. The upper part of the aorta and the oesophagus are supplied by ganglia Th. 1–5; their lower parts from the lower thoracic sympathetic ganglia either directly or via the splanchnic nerves.

Abdominal and Pelvic Viscera (*fig. 767*). These are supplied by the thoracic and lumbar splanchnic nerves Th. 6–L. 3 They are relayed in the celiac, intermesenteric, and hypogastric plexuses.

The Parasympathetic Nerves. Parasympathetic fibers are contained in cranial nerves III, VII, IX, and X, and in sacral nerves (2), 3 and 4.

The Oculo-motor Nerve (N. III) sends fibers to the ciliary ganglion, thence they are relayed by short ciliary nerves to the sphincter pupillae and ciliary muscle, mediating contraction of the pupil and accommodation (*fig. 718*).

The Facial Nerve (N. VII) (*fig. 744*). Efferent fibers travelling in the sensory root (pars intermedia) of the facial nerve carry secretory and vaso-dilator impulses to the lacrimal and salivary glands and glands of the nose, naso-pharynx and roof of the mouth, via (a) the *greater superficial petrosal nerve* to the spheno-palatine ganglion, thence by the zygomatic nerve to the orbit, thence to the lacrimal nerve and so to the lacrimal gland: other branches of the ganglion (*fig. 744*) distribute fibers to the glands of the nose, naso-pharynx and roof of the mouth, (b) the *chorda tympani*, after passing through the tympanum joins the lingual nerve, which brings fibers to the submandibular ganglion and so to the submandibular and sublingual glands. The chorda tympani is, therefore, both afferent and efferent; the afferent fibers are taste fibers, the efferent are secretory: and (c) a *small branch* of the facial nerve joins the lesser superficial petrosal nerve and so to the parotid gland.

The Glossopharyngeal Nerve (N. IX). The tympanic branch of the glossopharyngeal traverses the tympanum, receives a small branch from the facial, and as the *lesser superficial petrosal nerve*, passes to the otic ganglion, thence by the auriculo-temporal nerve to the parotid gland. Nerves VII and IX both supply the parotid.

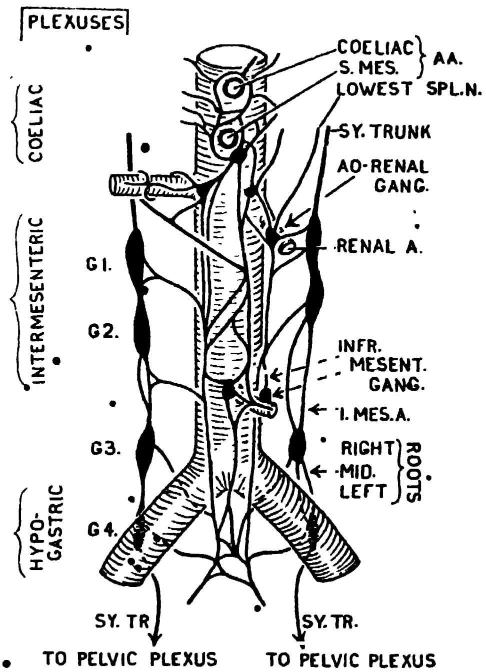


FIG. 767. The intermesenteric and hypogastric plexuses. (From a dissection by K. Baldwin.)

The *relay stations* of the preceding nerves are in the *ciliary*, *spheno-palatine*, *submandibular* and *otic ganglia*.

The Vagus (N. X) supplies the respiratory and digestive passages and the heart as described on page 713. It acts upon the involuntary muscle and carries secretory and vaso-dilator fibers. The vagus causes viscera to contract and empty their contents. The afferent fibers of the vagus do not carry impulses

of pain. The relay stations of the vagus are in the walls of the organs it supplies.

The Sacral Splanchnic Nerves (nervi erigentes) S. (2), 3 and 4 behave as vagal fibers and are described on page 367.

BODY TYPES OR BODILY HABITUS

Mills, as a radiologist working with large numbers of persons, recognised that healthy human beings differ from each other not only in outward appearance, form, and size, but also inwardly. He described two extreme physical types, the *hypersthenic* and the *asthenic* (*figs. 768, 769*) which are the antitheses of each other, and two intermediate types, the *sthenic* and the *hyposthenic*; and these have their subdivisions. All four types occur in healthy persons—in normal persons, if you wish.

He noted (1) that there are variations in general bodily physique and in the relative capacities of the thorax, upper abdomen, lower abdomen and pelvis; (2) that there are variations in the form, position, tone and mobility of the viscera; and—which is still more important—(3) that there are constant relationships between (1) and (2); that is, between physical types and visceral types. For example, a powerful, heavily built individual with short thorax and long abdomen has a wide lower thorax and upper abdomen and a small pelvis occupied with much fat. In such an individual (hypersthenic) the gastro-intestinal tract is placed high (*fig. 770*), the stomach being nearly horizontal, a condition that never obtains in those of slender physique (asthenic).

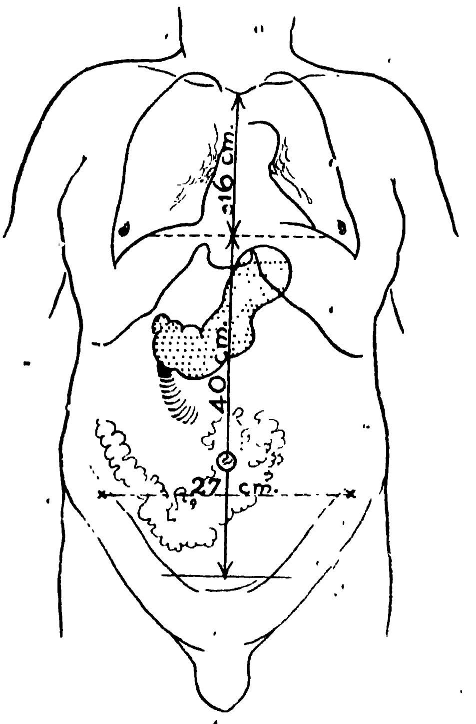


FIG. 768. Hypersthenic habitus.

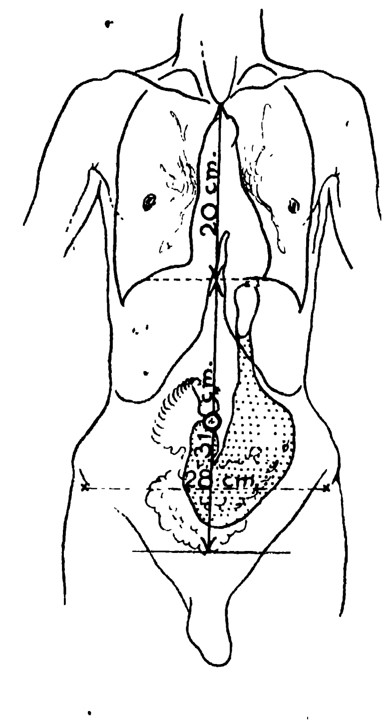


FIG. 769. Asthenic habitus.

Features of the Hypersthenic Habitus:

(a) A powerful and massive *physique*, great body *weight*, and heavy *bony framework*.

(b) The *thorax* is short, deep, and wide; the *abdomen* is long and of great capacity in its upper zone. The *subcostal angle* is very obtuse, and the xiphoid process is broad.

(c) The *lungs* are wide at their bases, and contracted at their apices which project but little above the clavicles.

The gastric motility is fast; there is marked tone and rapid motility of the colon. Defaecation takes place 2–3 times a day.

Features of the Asthenic Habitus:

(a) Frail and slender *physique*, light body *weight*, and delicate *bony structure*.

(b) The *thorax* is long and narrow; the *abdomen* is short. There is disproportion between the *pelvic capacity* and that of the upper abdomen, the false pelvis being

Fig. 770. (Left) Hypersthenic type. (Right) Asthenic type.

(d) The long axis of the *heart* is nearly transverse.

(e) The *gastro-intestinal tract* is high. The stomach is of the bull-horn type, the pylorus being the lowest, or nearly the lowest, part of the stomach. The entire colon is short; the caecum is well above the iliac basin even when the subject is standing; the transverse colon is short, actually transverse, and high; consequently the descending colon is long, it is also straight. The relative proportions of the colon are characteristic, so are its fine, numerous haustrations.

often as wide and capacious as that of a hypersthenic subject of twice the weight. The *subcostal angle* is narrow.

(c) The *lungs* are widest above, and their apices reach well above the clavicles.

(d) The long axis of the *heart* is approximately in the median plane.

(e) The *gastro-intestinal* tract is low. The stomach is atonic and largely pelvic when the subject is standing. The entire colon is long; the caecum is capacious and low in the pelvis; the

transverse colon dips down towards, or into, the pelvis; the haustrations of the colon are coarse. The tone of the gastro-intestinal tract is poor and its motility slow.

The characters of the viscera can apparently be related to certain governing factors: (a) General body architecture; a high, wide upper abdomen is a long abdomen and is necessarily associated with a short thorax, wide below; hence, the lungs are short and the heart is wide, and room is afforded highly placed abdominal viscera. (b) The alimentary tone in such persons is good, consequently the stomach is hypertonic and nearly horizontal and the transverse colon is high. This is made possible by the capacious upper abdomen. (c) If the metabolic need is great, much food is consumed; so an active, motile digestive system is required, essential to which are good gastro-intestinal tone and high position. (d) The state of nutrition influences the visceral topography by the presence or absence of space-occupying abdominal fat. (e) Strength and good tone in the skeletal muscles aids greatly in the hypersthenic habitus.

THE BONES OF THE SKULL

It is, generally speaking, much more important to be familiar with the skull as a whole than with the individual bones that comprise it, because (except in the cases of the mandible and the ossicles of the ear) the bones are united to each other by either suture or synchondrosis and there is no movement between them. Muscle attachments, bony fossae, bony lines and ridges, blood sinuses, fasciae and so on extend from bone to bone without respect to such joints, so the locations of the immovable joints that outline the individual bones are of little account. How different this is from the limbs, where the joints are of the first importance.

The bones of the skull may be classified as:

(a) Bones of the cranial cavity: frontal, parietal, occipital, sphenoid, ethmoid, and temporal. (Of these only the parietal and temporal are paired.)

(b) Bones of the face and nasal cavities: maxilla, zygomatic, palatine, nasal, lacrimal, inferior concha, vomer, and mandible. (Of these only the vomer and mandible are unpaired.)

The Frontal Bone is shaped like a cockle shell and has two parts: a vertical part, the *squama*, in the forehead; and a horizontal part, the two *orbital plates*, which forms the greater part of the roof of each orbit. Between the two orbital plates there is an oblong space, the *ethmoidal notch*.

Supra-orbital Margin and Outer Aspect of Squama. Between the squama and each orbital plate is the *supra-orbital margin*; this is concave, forms a third of the margin of the orbit, and has either a notch, foramen, or canal, the *supra-orbital notch* (f. or c.) 1¼ inches from the median plane. The supra-orbital margin ends laterally in a stout projection, the *zygomatic process*; medially it ends at a point, the *medial angular process*. Between the right and left medial angular processes there is a broad semilunar surface, the *nasal notch*, for articulation with the nasal bones and frontal processes of the maxillae. The point in the median sagittal plane between nasal and frontal bones, i.e., on the nasal notch, is the *nasion*. The prominence half an inch above the nasion is the *glabella*, so called because it is situated between the eyebrows and is bald or glabrous. Lateral to it on each side a fullness, the *superciliary arch*, extends to, or beyond, the supra-orbital notch. A sharp line, the *temporal line*, curves backwards from the zygomatic process and separates the temporal fossa below from the region of the scalp above. A fullness at the centre of each half of the squama, the *frontal eminence*, marks the site where ossification began. Vertical grooves for branches of the supra-orbital nerves are sometimes seen on the squama.

The Under Surface. Each orbital plate is very thin and brittle, and has laterally just behind the supra-orbital margin a *fossa* for the lacrimal gland, and medially a *spine* (or depression) for the trochlea of the Obliquus Oculi Superior. The ethmoidal notch lodges the cribriform plate of the ethmoid. Skirting the notch on each side are broken cells which overlie the ethmoidal labyrinth and form

the roofs of the *ethmoidal air cells* or *sinuses.* Two half-canals, *anterior* and *posterior ethmoidal canals,* run in the walls of the cells from orbit to ethmoidal notch. The most anterior cell (sometimes the second most anterior) opens into the *frontal air sinus.* Descending from the nasal notch is a broad triangular process, the *nasal spine.* In front it buttresses the nasal bones; behind these bones it articulates on each side with the frontal process of the maxilla; posteriorly

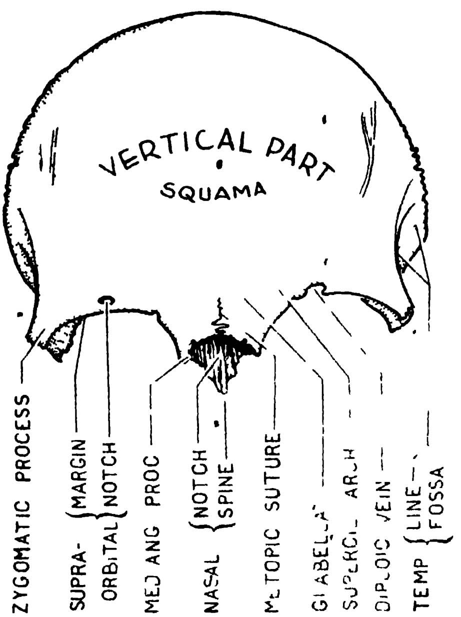


FIG. 771 Frontal bone from in front

it has a median crest for the vertical plate of the ethmoid, and on each side of this a longitudinal groove (4 mm. wide) forms part of the roof of the nasal cavity. The latter facts are best appreciated on inverting a skull and looking at the narrow roofs of the nasal cavities just above the nasal bones.

THE INNER OR CEREBRAL SURFACE takes part in the interior cranial fossa. A median ridge, the (internal) *frontal crest* extends upwards from the ethmoidal notch to a broad shallow groove, the *sagittal sulcus.* The upper surface of each orbital plate is convex and is marked by ridges which occupy sulci of the brain.

ARTICULATIONS. Just as you raise your hat from your head, so you may raise a frontal bone from off the other bones of the skull (nasal, maxillary, lacrimal, ethmoid, sphenoid and zygomatic), because it rests on them; it is true that at the upper part of the coronal (fronto-parietal) suture the frontal bone overlaps

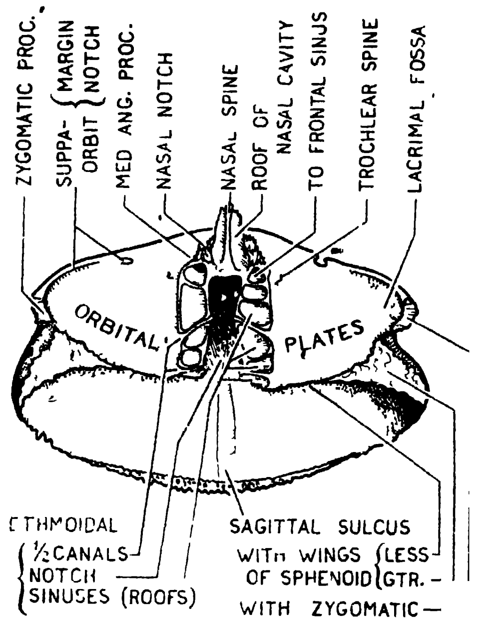


FIG. 772 Frontal bone—from below.

the parietal; however, at the lower part it is overlapped by the parietal.

OSSIFICATION is in membrane; it begins during the 7th foetal week at the frontal eminences. At birth the frontal bone is in two halves; these fuse about the fifth year at the interfrontal or *metopic suture.* Remnants of this suture persist at the glabella. The frontal air sinuses begin to invade the squama and orbital plates about the 2nd year.

The Parietal Bone is described on page 678.

Ossification is in membrane; it begins about the 7th foetal week at the parietal eminence, that is at the point of fullness at the centre of the bone. The parietal bone therefore corresponds closely to the frontal, but the two parietal bones do not fuse till the third decade. Areas around the margins of the parietal bone may ossify separately giving rise in the sutures to small independent bones, commonly the size of a finger nail, called *sutural* (*Wormian*) *bones.* Parietal bones divided into upper and lower halves have been observed.

The Occipital Bone (unpaired) lies at the back and base of the spheroidal brain case. At birth, and until the third or fourth year, it consists of 4 pieces, disposed around the *foramen magnum* thus: the squamous part or *squama* behind, a lateral or *condylar part* on each side, and the *basilar part* or basi-occiput in front. These names are retained for parts of the adult bone.

The Squama. Near the center of the outer surface of the squama is a boss, the *external occipital protuberance* or more briefly the *inion.* From the inion a line, the *superior nuchal line,* curves on each side to the lateral border, separating the area for the scalp above, from the area for the muscles of the neck, the *nuchal area,* below. A median crest, the *external occipital crest,* runs from inion to foramen magnum; and from near the mid-point on this crest an *inferior nuchal line* curves laterally on each side. Below the center of the inner surface is an elevation, the *internal occipital protuberance.* From it a cruciate arrangement of lines radiates. The upper lines bound the *sagittal sulcus*; two transverse lines on each side bound the *transverse sulcus*; and, a prominent median line, the *internal occipital crest* descends to the foramen magnum, occasionally splitting below to enclose a triangular depression, the *vermian fossa.* The cruciate lines divide the inner surface of the squama into four fossae—two upper ones for the occipital lobes of the cerebrum, and two lower ones for the hemispheres of the cerebellum. The upper fossae are covered externally merely by scalp, and the bone is thick; the lower fossae are protected externally by nuchal muscles, and the bone is thin and translucent.

The Condylar Parts. On the under surface of each condylar part (and extending on to the basilar part) an oval

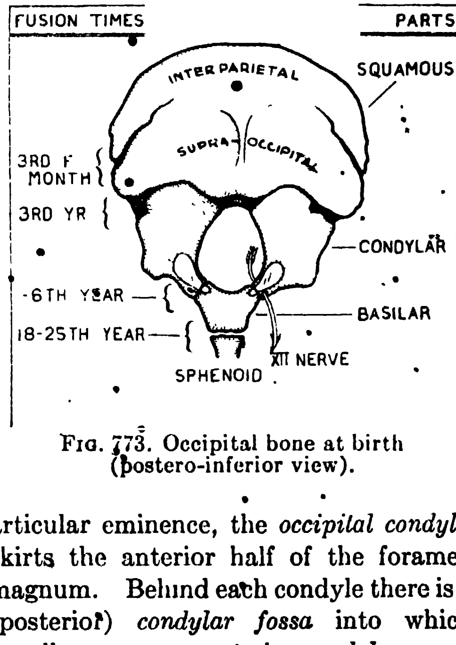


Fig. 773. Occipital bone at birth (postero-inferior view).

articular eminence, the *occipital condyle,* skirts the anterior half of the foramen magnum. Behind each condyle there is a (posterior) *condylar fossa* into which usually opens a *posterior condylar canal* for an emissary vein. Lateral to the posterior two thirds of each condyle projects a bar of bone, the *jugular process,* which is homologous with the transverse process of a vertebra. The anterior one third of each condyle extends forwards on to the basilar part of the bone. The site of union between the basilar and condylar parts is marked by the *anterior condylar* (*hypoglossal*) *canal,* for the transmission

of the hypoglossal nerve. The external orifice of this canal lies antero-lateral to the condyle; the internal orifice lies within the margin of the foramen magnum above the middle of the condyle and is overhung by the *jugular tubercle.* The jugular process is grooved both above and in front by the *sigmoid sinus,* which here becomes the internal jugular vein. Posteriorly it is continuous with the squama.

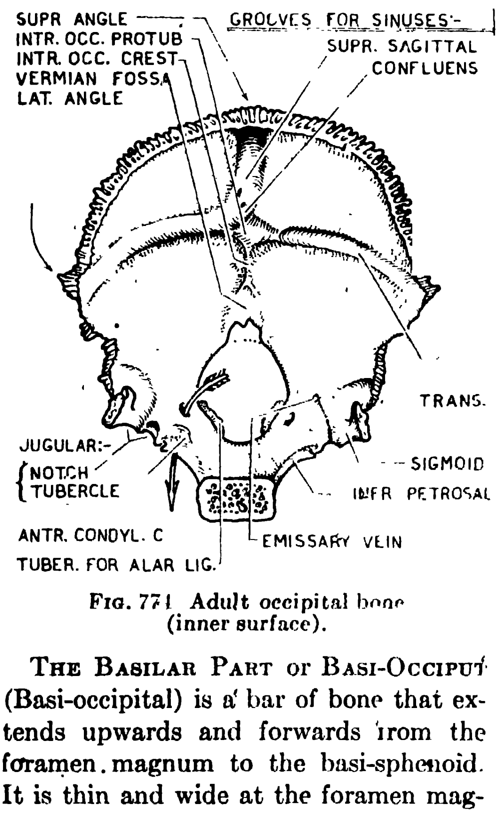


FIG. 771 Adult occipital bone (inner surface).

THE BASILAR PART OR BASI-OCCIPUT (Basi-occipital) is a bar of bone that extends upwards and forwards from the foramen magnum to the basi-sphenoid. It is thin and wide at the foramen magnum, but narrow and nearly square on cross-section where it joins the basi-sphenoid. Its cerebral surface, concave from side to side, supports the pons and medulla, and along each side has a half of the groove for the *inferior petrosal sinus,* the petrous temporal having the other half. Each lateral margin is united by synchondrosis to the petrous temporal bone until the 25th year or later, when synostosis occurs. The under surface carries one third of a condyle on each side, and in front of these are rough markings for the attachments of the Longus Capitis and Rectus Capitis Anterior. At the centre is the *pharyngeal tubercle* for the attachment of the fibrous median raphe of the pharynx.

ARTICULATIONS. With both parietals, both petrous temporals, the sphenoid and the atlas.

VARIATIONS. The occipital bone develops in cartilage, except the portion above the superior nuchal line, which develops in membrane; this superior part may fail to fuse with the rest of the bone thereby constituting an *interparietal bone.* The interparietal bone itself develops from several centres any of which may remain discrete, thereby simulating a large sutural bone. The *paramastoid process* is an occasional bar of bone that descends from the jugular process towards the transverse process of the atlas. The *third occipital condyle* is an occasional tubercle that projects from the anterior border of the foramen magnum to articulate with the dens of the axis. A *median cleft* may extend from the foramen magnum backwards into the squama. It is due apparently to the nonappearance of an ossific centre (*fig. 773*). *Fusion of* the *atlas* and *occipital bone* may occur, especially at their condyles.

The Sphenoid Bone. Viewed from in front the sphenoid resembles a bat or an owl with wings outstretched and legs dependent. It extends across the base of the skull, articulates with numerous bones, takes part in many fossae and possesses many foramina. It comprises a body, two lesser wings, two greater wings and two pterygoid processes. At birth it is in 3 pieces, the body and lesser wings forming one piece, the greater wing

and pterygoid process on each side forming the other two pieces. It becomes one bone during the first year. The cubical body contains two air sinuses, the right and left sphenoidal air sinuses (*fig. 646*).

THE BODY AND LESSER WINGS—viewed from above. The attenuated lesser wing of each side has a free concave posterior border which ends medially in a blunt triangular spine, the *anterior clinoid process* or bedpost. Medial to this it is attached to the anterior half of between these with the ethmoid, which it also overlaps (*fig. 775*).

The posterior edge of the jugum is also the anterior edge of a groove, the *optic groove* (chiasmatic sulcus), that connects the optic foramina of opposite sides. The part of the body behind the optic groove is the *sella turcica* (Turkish saddle); it is subdivided into a pommel, a seat and a back. The pommel of the saddle is a transversely set olive-like eminence, the *tuberculum sellae*, each end

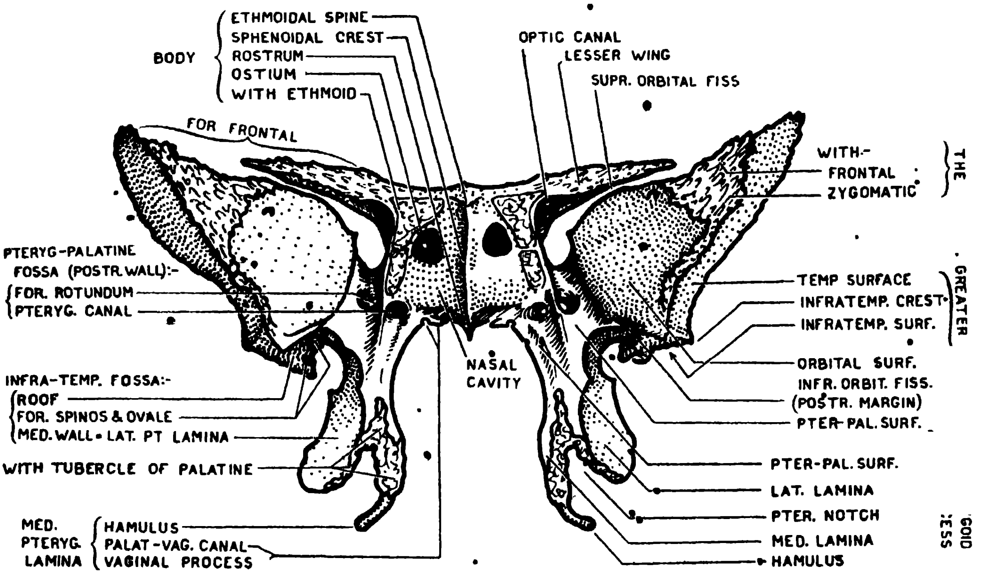


FIG. 775. Sphenoid bone—from in front.

the body by two roots which bound the *optic foramen* above and below. After birth the upper roots of the two sides extend like sliding doors across the upper surface of the anterior half of the body and joining form a yoke, the *jugum*, which conceals this part of the body. The upper surface of the lesser wings and jugum forms the hinder part of the anterior cranial fossa. This surface is narrow and flat, and is pointed at each lateral end; in front it articulates with the orbital plates of the frontal bone and of which may form a spine, the *middle clinoid process.* Behind the tuberculum sellae is the excavated seat, the *hypophyseal* or *pituitary fossa.* Behind this rises a square plate of bone, the *dorsum sellae*, whose upper angles are tubercular, the *posterior clinoid processes* or bedposts.

The side of the hollow body gives attachment antero-inferiorly to the greater wing; postero-inferiorly it articulates with the apex of the petrous temporal; and between these lies the foramen lacerum where the internal carotid artery enters

the skull. Between the foramen and the anterior clinoid process the bone is faintly grooved by the artery. The side of the body extends forwards beyond the optic foramen, superior orbital fissure, and foramen rotundum.

The hinder part of the body is a square "epiphyseal" surface, which fuses with the basi-occiput before the 25th year.

The anterior surface of the body has a median crest, the *sphenoidal crest*, which forms part of the nasal septum. This crest begins above in a spine, the *ethmoidal spine*, and ends below in a beak, the *rostrum*, which is received between the alae of the vomer. A vertical triangular area at the side of the sphenoidal crest forms part of the roof of the nasal cavity. Near the midpoint of this area is the orifice of the *sphenoidal air sinus*. Lateral to this the body articulates with the ethmoidal labyrinth. The mouths of *5 bony passages* lie grouped at the side and under aspect of the front of the body. They are: (a) the optic foramen between the roots of the lesser wing, (b) the foramen rotundum at the root of the greater wing, (c) the pterygoid canal at the root of the pterygoid process, also (d) the superior orbital fissure between the lesser and greater wings, and (e) the palatino-vaginal canal below the vaginal process. The sphenoidal sinus is liable to infection and this may spread to the structures passing through the passages just named —particularly the first three. The anterior (antero-inferior) surface of the lesser wing forms the hinder part of the roof of the orbit.

THE GREATER WING projects from the side of the body and its inner or cerebral surface forms the anterior part of the lateral subdivision of the middle cranial fossa. It is separated from the lesser wing by a comma-shaped fissure, the *superior orbital fissure*, which opens from the middle cranial fossa to the orbit. The *foramen rotundum* is situated below the medial end of the superior orbital fissure, and passes forwards through the root of the greater wing to the pterygo-palatine fossa. This fossa lies below the level of the orbit and is seen from the side of the skull. Behind its site of attachment to the body, the wing has a posterior border which ends postero-laterally in an angle. On the under surface of the angle there is a spine, the *spine of the sphenoid*. The posterior border grew around and engulfed the mandibular nerve thereby forming the *foramen ovale* and more laterally, at the root of the angular spine, it engulfed the middle meningeal artery thereby forming the *foramen spinosum*. These two foramina open downwards into the infra-temporal fossa. The small superficial petrosal nerve may be similarly engulfed resulting in the formation of a third foramen, the *canaliculus innominatus*—a minute foramen between the foramen ovale and foramen spinosum. The superior orbital fissure, the foramen rotundum, the foramen ovale, and the foramen spinosum lie on a crescent (*fig.* 648). The wing is grooved near its tip by the anterior branch of the middle meningeal artery.

The greater wing forms part not only of the middle cranial fossa, but also of the orbit, and of the temporal, infratemporal and pterygo-palatine fossae. Between the temporal and infratemporal surfaces, which are set at a right angle to each other, is the sharp and often spinous *infratemporal crest*.

THE PTERYGOID PROCESS descends obliquely from the junction of the body and greater wing. It consists of two plates, the *medial* and *lateral pterygoid laminae*. They are fused in front, but free behind and below. Between them is the *ptery-*

goid fossa. At the lower end of the posterior border of the medial pterygoid lamina is a delicate hook, the *hamulus*, at the upper end is a conical tubercle, *pterygoid tubercle*. This tubercle is the guide to the *pterygoid canal*, which lies just above and passes forwards to the pterygo-palatine fossa, where lies the spheno-palatine ganglion From the root border is free and sharp for the pharyngeal aponeurosis and has a spine for the support of the mouth of the pharyngo-tympanic tube. The lateral lamina forms the medial wall of the infra-temporal fossa. Its posterior border is free and serrated; followed upwards it leads to the foramen ovale. Its medial surface gives origin to the Medial Pterygoid, its

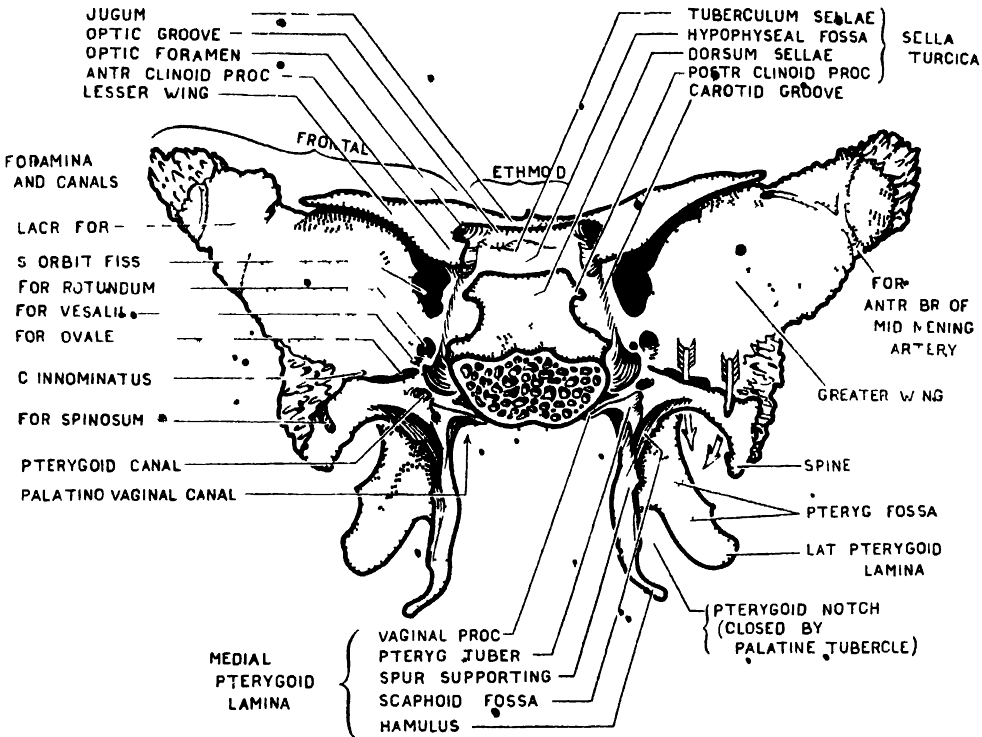


FIG 776 Sphenoid bone—from behind

of the medial lamina a plate, the *vaginal process*, runs medially towards the ala of the vomer. On the under surface of this process a groove or canal, the *palatino-vaginal canal* runs backwards. The supero-medial part of the pterygoid fossa is carried backwards towards the spine of the sphenoid as a sharply defined fusiform fossa, the *scaphoid fossa*. The medial lamina forms part of the lateral wall of the nasal cavity. Its posterior lateral surface to the Lateral Pterygoid – so it is a muscular process.

OSSIFICATION (*fig. 646*). The body and lesser wings develop in cartilage; so does the root of the greater wing and its downgrowth, the lateral pterygoid lamina. The remainder of the greater wing develops in membrane. The medial pterygoid lamina also develops in membrane, and its line of fusion with the body and greater wing is usually obvious—it

runs above the vaginal process and pterygoid tubercle and crosses through the pterygoid canal. Further, two paired fragments ossify independently in cartilage: one is a curved plate of bone, the *lingula*, which lies above the posterior orifice of the pterygoid canal and sweeps medially behind the carotid artery; the other is a triangular plate, the *sphenoidal concha*, which is applied to the anterior and inferior surfaces of the body of the sphenoid. About the third year the mucous membrane of the nasal cavity bursts through the right and left sphenoidal conchae into the body of the sphenoid,

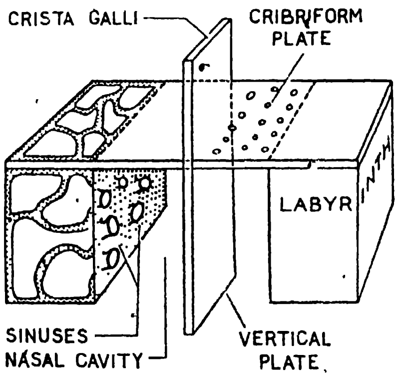


FIG. 777. Scheme of ethmoid bone.

thereby forming the right and left *sphenoidal air sinuses*.

VARIATIONS. The septum between the right and left sinuses is usually greatly deflected. 'The sinus is commonly over-inflated, so to speak,' with the result that it partly surrounds the optic foramen (canal), the pterygoid canal, and the foramen rotundum so that they project as ridges within it. The walls of the ridges may be resorbed; the optic nerve, nerve of the pterygoid canal, the maxillary nerve and also the cavernous sinus and carotid artery are then brought close to the muco-periosteum of the sinus.

The Ethmoid Bone may be likened to a St. George's cross made of planks and having an oblong box suspended from each end of the cross-piece. The boxes are the *ethmoidal labyrinths*; the cross-piece is the *cribriform plate* (lamina cribrosa); the part of the upright above the cribriform plate is the *crista galli*; and the part below is the *vertical* or *perpendicular plate*.

The ethmoid is developed from the cartilaginous nasal capsule. *At birth* it is in 3 pieces—a median plate, and a right and a left labyrinth. The median plate, which forms part of the nasal septum, and the crista galli (cock's comb), which is its upward extension into the anterior cranial fossa, are cartilaginous; these begin to ossify during the first year. The labyrinths, however, are bony at birth and are joined to the median plate by a fibrous lamina cribrosa. Fusion is complete by the fifth or sixth year.

The *crista galli* is thick and triangular. The falx cerebri is attached to its posterior border and apex; the anterior border splits into two *alae* which, with the frontal bone, enclose the *foramen caecum*. The *cribriform plate* is a fragile, sieve-like plate lying at each side of the crista galli and occupying the ethmoidal notch of the frontal bone. It forms part of the floor of the anterior cranial fossa and of the roof of the nasal cavities. Through the perforations pass the olfactory nerves in their arachnoid coverings, also the anterior ethmoidal nerve and nasal branches of the anterior and posterior ethmoidal arteries—the anterior ethmoidal nerve and artery passing through a special opening, the *nasal slit*. The *vertical plate* forms the postero-superior third of the nasal septum (*fig. 745*).

THE LABYRINTH. Each box-like labyrinth is composed of a dozen or less air cells, the *ethmoidal sinuses*, which open medially into the nasal cavity; laterally, it has a smooth, oblong, fragile wall, the

orbital plate (lamina papyracea); above, it is covered by the medial part of the orbital plate of the frontal bone and slightly by the sphenoid. The cells in places break through the (bony) walls of the labyrinth; those that break through the roof proper adopt the orbital plate of the frontal as their new roof, and one cell (or more) constantly extends even into the frontal bone itself and becomes the *frontal air sinus*, its stalk being the *infundibulum*; others are limited by the surrounding lacrimal, maxillary, palatine and sphenoid bones. From the hinder part of the medial surface of the laby-

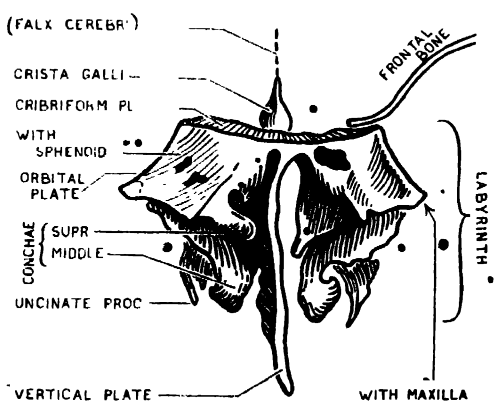


FIG. 778. Ethmoid bone—from behind.

rinth a scroll, the *superior concha*, hangs downwards; and the medial surface itself continues downwards as the *middle concha*. A hook of bone, the *uncinate process*, curves backwards from the anterior end of this surface to meet the corresponding process of the inferior concha, thereby forming the lower limit of the hiatus semilunaris. The oblong posterior surface of the labyrinth abuts against the anterior surface of the body of the sphenoid.

The Temporal Bone is a composite bone, situated at the base and side of the skull between the sphenoid in front and the occipital behind. At birth it is in 3 parts—the squamous, tympanic, and petro-mastoid—which fuse during the first year. The inner ear lies within the petrous part. The tympanic cavity, which developed from the first and second visceral clefts, is enclosed by the three parts of the bone; it communicates with the tympanic (mastoid) antrum behind, and with the naso-pharynx in front via the pharyngo-tympanic (auditory) tube. Through the bone runs the facial nerve. The squamous and tympanic parts develop in membrane, the petro-mastoid in cartilage.

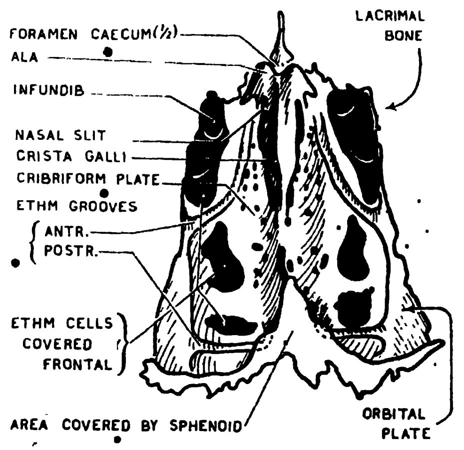


FIG. 779. Ethmoid bone—from above.

THE SQUAMOUS PART or Squama, resembling a pilgrim's shell, forms part of the lateral wall of the cranium. Its medial surface, described fully on page 628, is grooved by the middle meningeal artery. From the lower part of its lateral surface the finger-like *zygoma* (zygomatic process) curves forwards (*page 677*). On the under surface is a translucent, oval socket, the *mandibular* (articular) *fossa* for the head of the lower jaw (*p. 692*). An angular part, the *post-auditory process*, described in the adult bone as part of the mastoid, projects downwards for half an inch below the level of the

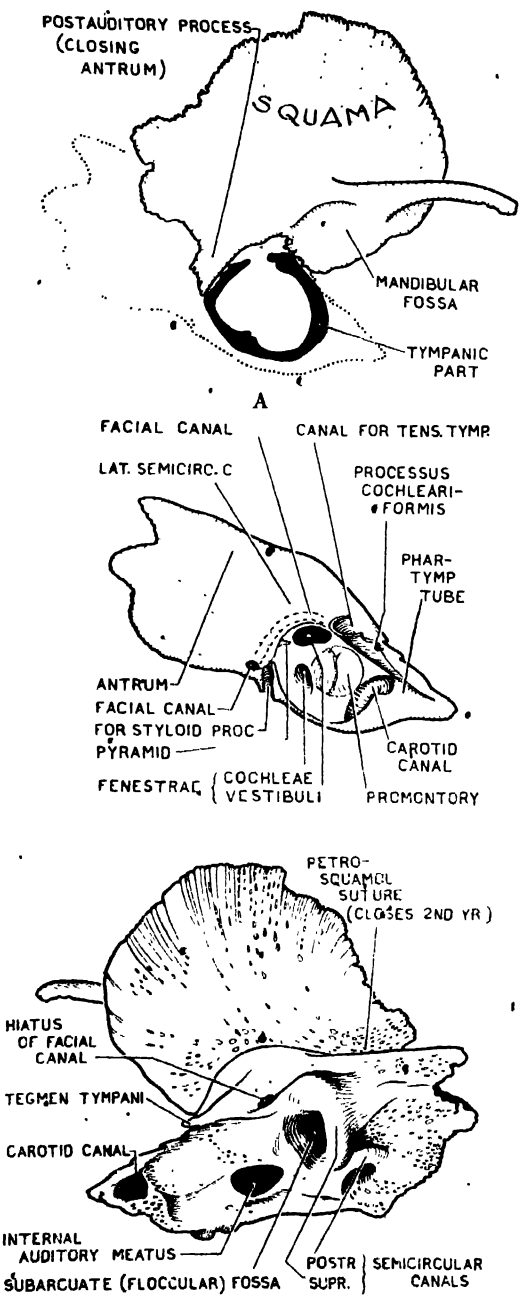


FIG. 780. The 3 parts of the temporal bone at birth. A. Lateral aspect of squamous and tympanic parts. B. Lateral aspect of petromastoid part. (The squamous and tympanic parts have been removed to show the medial wall of the tympanum and tympanic antrum.) C. Inner aspect.

middle cranial fossa, closing the tympanic antrum laterally.

THE TYMPANIC PART at birth is a ring open above. It is grooved for the tympanic membrane, and attached to it laterally is the cartilage of the external auditory meatus. During the early years of life the ring becomes oval and elongated to form the anterior wall, floor, and lower part of the posterior wall of the bony external auditory meatus. It also extends downwards into a plate, the *tympanic plate,* which forms the posterior wall of the mandibular fossa and, splitting below to form the *vaginal process,* partly ensheaths the styloid process.

THE PETRO-MASTOID PART is the most important and also the most difficult part of the bone to understand. Its surfaces have been dealt with (*pp. 620, 630, 706*) In brief: it is pyramidal; its base is lateral; its apex is medial lying at the foramen lacerum. It has three surfaces—an anterior and a posterior, which form parts of the middle and posterior cranial fossae respectively, and an inferior which forms part of the under surface of the base of the skull. The *carotid canal* begins on the under surface of the bone and takes an inverted L-shaped course through it, opening into the foramen lacerum at the apex. The hinder part, the *mastoid bone,* is grooved internally, at its junction with the petrous, for the *sigmoid sinus;* externally it is prolonged downwards into a nipple, the *mastoid process,* but this is not present during the first year of life, so the *stylo-mastoid foramen,* situated where its name suggests, opens subcutaneously and there discharges the facial nerve.

For features of the anterior or cerebral surface see also fig. 647, for features of the posterior or cerebellar surface see fig. 645, and for features of the inferior surface see fig. 706.

The Maxilla or upper jaw (paired) has

a body and 4 processes. The body is a hollow pyramid with 3 surfaces, an apex and a base. The most conspicuous fea-

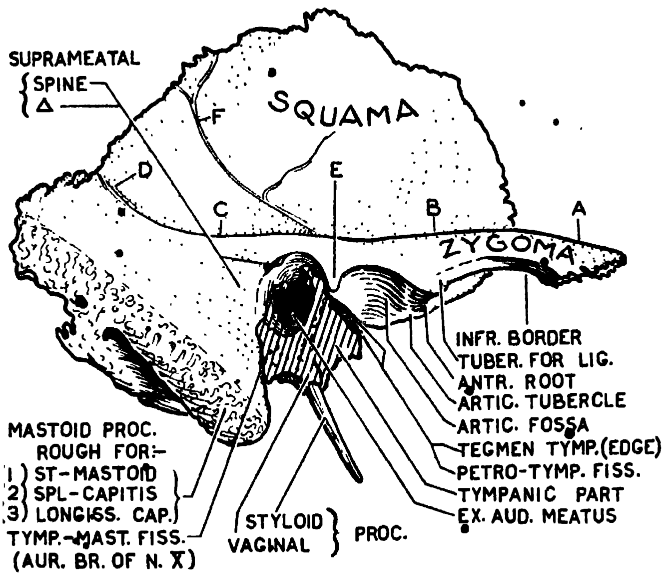


FIG. 781. Temporal bone—lateral aspect.

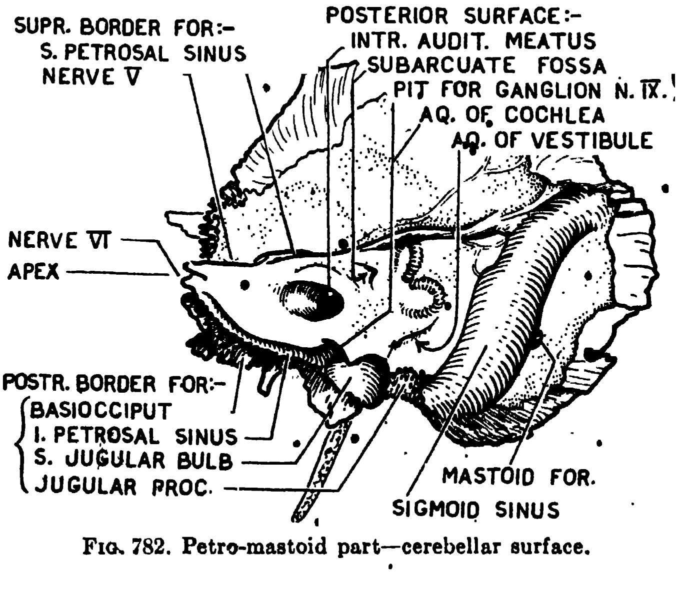


FIG. 782. Petro-mastoid part—cerebellar surface.

ture of the bone is the *alveolar process.* It carries eight teeth, each in its own socket, and ends behind the 3rd molar tooth in a free rounded part, the *maxillary tuberosity* (*fig.* 785). As in the lower jaw so in the upper, the roots of the teeth (2nd and 3rd molars excepted) cause ridges on the thin outer wall of the alveolar process, but not on the thick inner wall, that for the canine tooth being the largest. From the 1st or 2nd

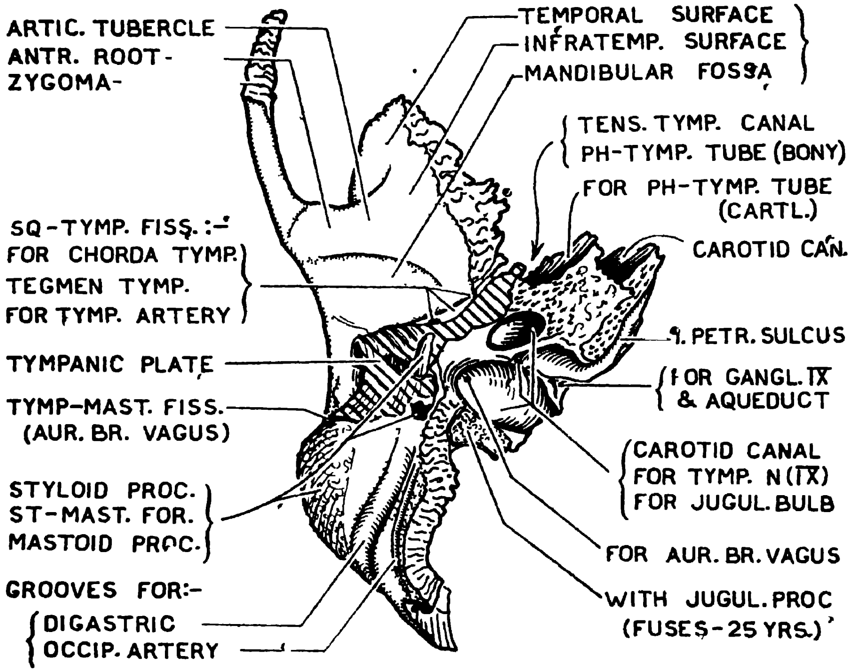


FIG. 783. Temporal bone—inferior aspect

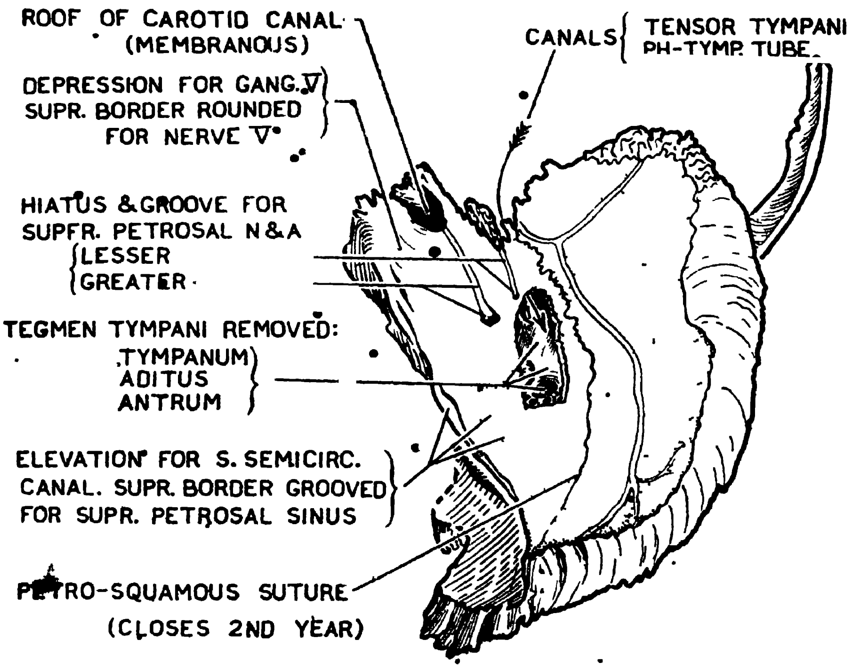


FIG. 784. Petrous part—cerebral surface.

molar tooth a rounded buttress ascends to the lower end of a large triangular prominence, the *zygomatic process,* which forms the truncated apex of the bone and is placed where the 3 surfaces (orbital, facial and infra-temporal) meet. It ends in a rough triangular area for articulation with the zygomatic bone. The buttress and the process separate the facial or anterior surface from the infra-temporal or posterior surface.

THE FACIAL (ANTERIOR) SURFACE is flat on a powerful skull, like that of the Eskimo, but concave in skulls of white races. The area medial to the ridge for the canine tooth, i.e., between the incisor teeth and the anterior nasal orifice, is the *incisive fossa;* the area lateral to this ridge is the *canine fossa.* Opening on to the canine fossa is the *infra-orbital foramen,* i.e., the anterior orifice of the infra-orbital canal. It is placed 1 cm. below the infra-orbital margin and its direction contrasts with that of the mental foramen in the mandible, since it opens infero-medially. The *infra-orbital canal,* can be followed backwards below the infra-orbital margin to the middle of the orbital surface where, ceasing to have a roof, it becomes the *infra-orbital groove;* this in turn may be followed backwards to the upper border of the infra-temporal surface. The facial surface is limited superiorly by the infra-orbital margin and is continuous supero-medially with the lateral surface of the frontal process.

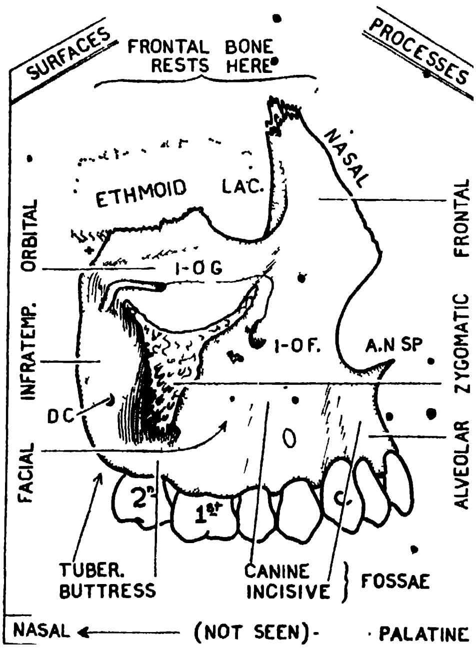


FIG. 785. Maxilla—lateral aspect.

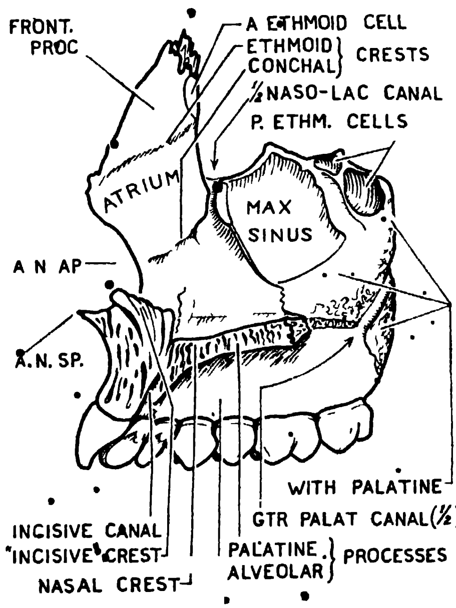


FIG. 786. Maxilla—medial aspect.

D. C. = dental canals; I-O. G. and I-O. F. = infraorbital groove and canal; A. N. Sp = Anterior nasal spine; + = space for orbital process of palatine bone

THE FRONTAL PROCESS is triangular. Its apex articulates with the nasal notch of the frontal bone; its anterior border supports the nasal bone; its posterior border articulates with the lacrimal bone. The infra-orbital margin is continued, as

the (anterior) *lacrimal crest*, on to the lateral surface of the frontal process, dividing it into a convex area, which is part of the bridge of the nose, and a concave area, the *lacrimal groove*. The medial or nasal surface of the frontal process is partly crossed by an oblique crest, the *ethmoidal crest*, for the attachment of the middle concha. Two-thirds of an inch below this, on the body of the maxilla, there is a second oblique crest, the *conchal crest*, for the attachment of the inferior concha. The area between the crests is part of the *atrium* of the

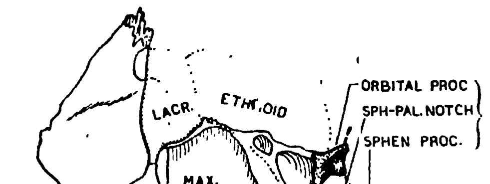


FIG. 787. Palatine bone (stippled) in articulation with maxilla—medial aspect.

middle meatus of the nose. Above the upper crest a small area forms the anterior wall of an ethmoidal cell.

THE INFRATEMPORAL (POSTERIOR) SURFACE is smooth, convex, and perforated near its centre by one or more *posterior dental foramina*. The part of this surface just above the tuberosity is buttressed by the pterygoid laminae (the tubercle of the palatine bone intervening as a buffer) and the part above this is the anterior wall of the *pterygo-palatine (pterygo-maxillary) fossa*, wherein resides the spheno-palatine ganglion.

THE ORBITAL (SUPERIOR) SURFACE is smooth, triangular, and slightly concave. Its apex extends on to the zygomatic process; its anterior border is the infra-orbital margin; its posterior border is the anterior margin of the inferior orbital fissure; its medial border is formed by the margin of the naso-lacrimal notch and behind this by articular areas for the lacrimal, ethmoid, and palatine bones. The surface is crossed posteriorly by the *infra-orbital groove*. Just lateral to the naso-lacrimal notch there is a *depression* for the origin of the Obliquus Oculi Inferior.

THE NASAL (MEDIAL) SURFACE is the base of the hollow pyramidal body. Its anterior ⅔ is separated from the alveolar process by a horizontal plate, the *palatine process*. The nasal surface presents, in the disarticulated bone, an opening large enough to admit the thumb. This is the *orifice of the maxillary air sinus* or antrum of Highmore. Between this and the frontal process is a groove (lacrimal groove) which forms two-thirds of the circumference of the *naso-lacrimal canal*. The part of the nasal surface behind the maxillary orifice is overlaid by the palatine bone; and when this is in position a perpendicular canal, the *greater palatine canal*, is formed. The maxillary half of this canal is continued forwards as two grooves on the under surface of the palatine process of the maxilla.

The medial border of the palatine process is slightly raised and with its fellow forms the *nasal crest*, which articulates with the vomer and forms part of the nasal septum. Its most anterior part is markedly raised to form the "*incisive crest*," which ends anteriorly on the face as the *anterior nasal spine*.

The part of the bone carrying the incisor teeth is the *premaxilla*, which in most mammals is an independent, paired

bone. It extends backwards to the junction of the nasal and "incisive" crests where a canal, the *incisive canal*, passes from its nasal to its oral surface.

OSSIFICATION. The maxilla proper ossifies in membrane from a single centre; the premaxilla ossifies from two centres or perhaps more. At birth the maxillary sinus is the size of a pea, and it enlarges as the teeth erupt. At birth the infra-orbital nerve lies free on the floor of the orbit just as the supra-orbital nerve lies free on the roof. As the maxilla enlarges the nerve sinks into a groove whose lateral edge then folds over the nerve, thus forming the infra-orbital canal and foramen.

The Zygomatic Bone is described on page 679.

OSSIFICATION is in membrane from a single center. The bone may be in two pieces, so evidently there may be more than one center.

The Palatine Bone (paired) gives many students undue concern. It is a fragile L-shaped bone comprising an oblong vertical plate, a square horizontal plate, and 3 processes the tubercle, the orbital process, and the sphenoidal process.

PLATES. *The vertical or perpendicular plate* forms the portion of the lateral wall of the nasal cavity just in front of the medial pterygoid lamina. It is applied to the hinder part of the nasal surface of the maxilla, but projects backwards behind this so as to form the medial wall of the pterygo-palatine fossa (seen from the side of the skull) and projects forwards closing the hinder part of the opening into the maxillary sinus. *The horizontal plate* articulates with its fellow to form the posterior third of the bony palate, the site of union being raised to form a *nasal crest*, for articulation with the vomer and ending behind in the *posterior nasal spine*. The anterior border of this plate articulates with the palatine process of the maxilla; the posterior border is sharp and concave.

PROCESSES. An inverted pyramid, the *tubercle* (pyramidal process) projects from behind the lower part of the vertical plate and interposes itself like a buffer between the posterior border of the maxilla (just above the tuberosity) and the medial and lateral pterygoid laminae of the sphenoid. The tubercle has a gutter for each lamina, and between the gutters a triangular area forms the lowest part of the pterygoid fossa. Surmounting the upper border of the vertical plate

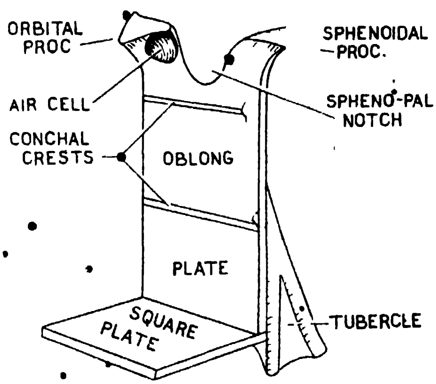


FIG. 788. Scheme of palatine bone.

are the orbital and sphenoidal processes, separated from each other by the U-shaped spheno-palatine notch—much as the head and coronoid process of the mandible are separated by the mandibular notch. *The orbital process* forms the hindermost 3–4 mm. of the floor of the orbit. It is a hollow box, hollowed by an extension from the sphenoidal sinus or the maxillary sinus or a posterior ethmoidal sinus. *The sphenoidal process* is a small plate applied to the under surface of the body of the sphenoid and reaching to the ala of the vomer. It converts the groove below the vaginal process of the sphenoid into the *palatino-vaginal canal*.

(pharyngeal canal). *The spheno-palatine notch* is converted by the sphenoid into the spheno-palatine foramen; it is the gateway to the nasal cavity.

THE GREATER PALATINE CANAL runs between the body of the maxilla and the vertical plate of the palatine bone and opens between the alveolar process of the maxilla and the horizontal plate of the palatine bone as the greater palatine foramen, while 2 *lesser palatine canals* descend from the greater palatine canal through the tubercle and open on to its under surface (*fig. 787*)

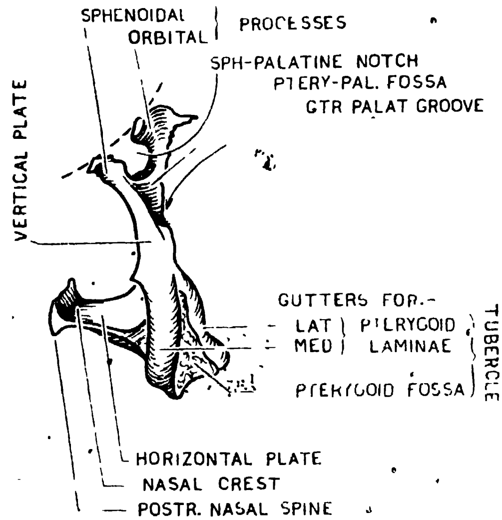


FIG. 789. Palatine bone posterior aspect

OSSIFICATION is from a single centre in the membrane in the lateral wall of the nasal cavity. The vertical plate is the primitive plate, the horizontal is secondary.

The Nasal Bone (paired) is small and stout; it is triangular with truncated apex above. It has two surfaces (inner and outer), two borders, an apex, and a base. The *apex* is blunt, thick, and serrated; it articulates with the nasal notch of the frontal bone. The *base* is broad, thin, and notched; attached to it is the upper lateral nasal cartilage. The *lateral* (postero-lateral) *border* is thin; it articulates with the frontal process of the maxilla. The *medial border* is a rather flat, triangular area which articulates with its fellow. The outer or *facial surface* of the paired bones is saddle-shaped, being convex from side to side and concave from above downwards. Near the centre is a foramen for an emissary vein from the nasal mucosa. The inner or *nasal surface* of the paired bones presents

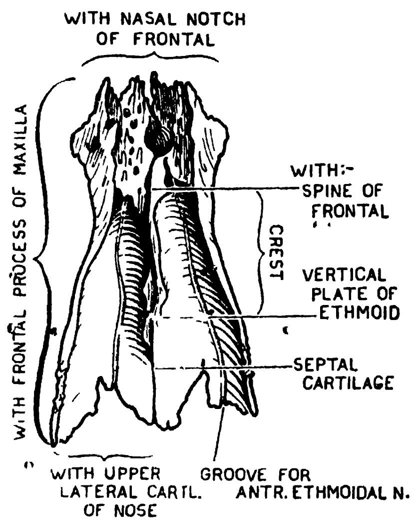


FIG. 790 Nasal bones articulated—posterior aspect.

a median *crest* which articulates with the nasal spine of the frontal bone above, with the vertical plate of the ethmoid below, and perhaps with the septal cartilage still lower—depending upon how far the vertical (perpendicular) plate of the ethmoid has replaced the septal cartilage (*see fig. 745*). Lateral to the crest, the nasal surface of each bone is concave from side to side, grooved longitudinally for the anterior ethmoidal nerve, and covered with mucous membrane.

The paired bones form the upper part of the bridge of the nose. The brunt of

a blow on the nose is transmitted from the nasal bones to the frontal processes of the maxillae, the nasal notch and spine of the frontal, the vertical plate of the ethmoid, and septal cartilage. The nasal bone develops in the membrane covering the cartilage of the nasal capsule.

The Lacrimal Bone (paired) resembles a fingernail but is much thinner. It has two surfaces (lateral and medial) and four borders which articulate thus in front with the frontal process of the maxilla, behind with the orbital plate of the ethmoid, above with the orbital plate of the frontal, and below with the orbital plate of the maxilla. The lateral surface

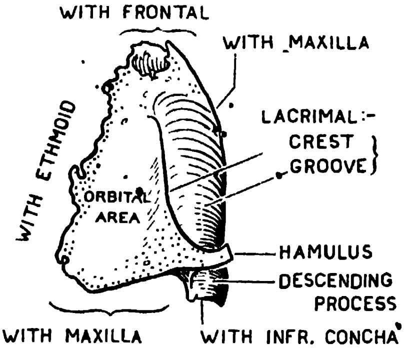


FIG. 791. Lacrimal bone—lateral aspect.

is divided into an anterior and a posterior part by a razor-like crest, the (posterior) *lacrimal crest*, which gives attachment to the palpebral fascia and to the Pars Lacrimalis of the Orbicularis Oculi. The crest ends below in a hook, the *hamulus*, which may or may not reach the margin of the orbit. The posterior part of this surface is flat and forms part of the medial wall of the orbit. The anterior part, the *lacrimal groove*, together with the grooved surface on the frontal process of the maxilla, forms a half-tube in which lodges the lacrimal sac. This part is prolonged downwards into a *descending process* which articulates with the lacrimal process of the inferior concha and with it forms the medial wall of the naso-lacrimal canal. The medial or nasal surface of the lacrimal bone is covered with mucous membrane. A needle perforating it from the lateral surface will enter the atrium of the middle meatus of the nose, unless the perforation is made posteriorly when it will enter an ethmoidal cell, or made above when it will enter either the infundibulum of the frontal sinus or an intervening ethmoidal cell. The lacrimal bone ossifies in membrane.

The Inferior Concha or turbinate bone (paired) hangs downwards like a scroll from the side wall of the nasal cavity.

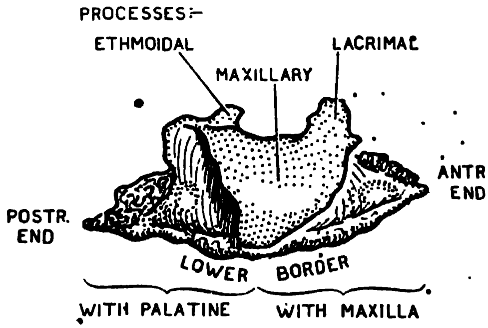


FIG. 792. Inferior concha—lateral aspect.

In the articulated skull it can be seen from the anterior and posterior apertures of the nose because it extends from a crest on the frontal process of the maxilla to a crest on the vertical (perpendicular) plate of the palatine bone. The lower border is thickened and gently curved, and the ends are pointed. There are three fragile processes one is large and downturned, two are small and upright. The *maxillary process* curves downwards and laterally and forms part of the medial wall of the maxillary sinus; it is large, thin and triangular. The *lacrimal process* ascends from near the anterior end of the maxillary process and, by joining the descending process of the lacrimal bone;

completes the naso-lacrimal canal medially. The *ethmoidal process* ascends from near the posterior end of the maxillary process and, by joining the uncinate process of the ethmoid, completes the lower border of the hiatus semilunaris of the middle meatus of the nose. The inferior concha ossifies in the cartilage of the nasal capsule.

The Vomer or plowshare (unpaired) forms the entire postero-inferior third of the nasal septum. When the skull is viewed from behind the free posterior border is seen dividing above into right and left alae. Viewed from the front the oblique anterior border is seen to be

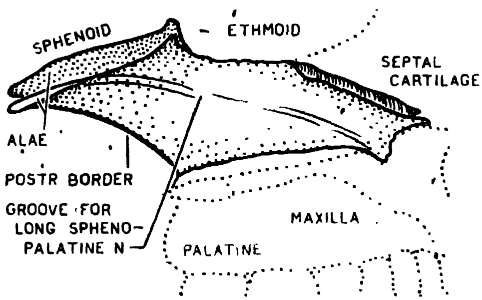


FIG. 793. Vomer—right side.

grooved in its lower part to receive the septal cartilage, and to be thin in its upper part for articulation with the vertical plate of the ethmoid. Each surface is grooved longitudinally by the long spheno-palatine (naso-palatine) nerve and companion vessels.

The vomer develops in the postero-inferior part of the membrane that lies on each side of the "primitive" septal cartilage. The intervening cartilage is absorbed thus allowing the membrane bones of the opposite sides to fuse; evidence of the bilateral origin of the vomer is still seen, however, in the groove for the septal cartilage and in the alae.

The Mandible is described on page 680.

OSSIFICATION. The lower jaw is the second bone in the body to start ossifying (sixth foetal week), the clavicle being the first. Each half of the jaw ossifies from a single centre which appears in the membrane overlying the anterior half of Meckel's cartilage, i.e., the cartilage of the first or mandibular arch. In front of the mental foramen, however, ossification involves a small part of Meckel's cartilage, and posteriorly the

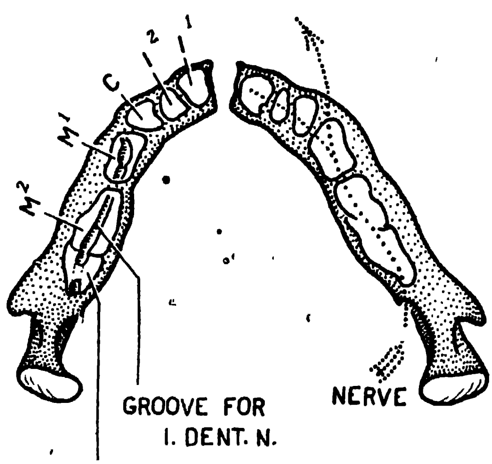


FIG. 794. Mandible at birth.

condyle and part of the coronoid process passed through a cartilaginous stage.

At birth each half of the jaw is a fragile trough in which the five milk teeth and sixth year molar (i.e., first permanent molar) lie buried. The mandibular canal —in part open above—runs along the bottom of the trough. The ramus meets the body at a very obtuse angle, the two being almost in line. The eruption of the teeth separates the upper and lower jaws, hence the angle decreases; conversely, it increases again if the jaws become edentulous. Growth takes place mainly through additions to the outer

surface of the bone and to the posterior and inferior borders.

The Hyoid Bone is shaped like the letter U, hence its name (Gk. (H)U-eidos = U-like). It comprises a quadrate middle part, the *body*, and two processes on each side, the *greater* and *lesser horns* (cornua). Muscles ascend to the hyoid and muscles descend to the hyoid, but no muscle crosses it, so the entire length of the bone (from the tip of one greater horn to the tip of the other) is subcutaneous externally and submucous internally (*fig. 753*). It is readily palpated at the angle where the upper part of the neck meets the floor of the mouth (*pp. 649, 650*). Theoretically, the simplest way to open the pharynx is (1st) to cut transversely through the skin, (2nd) to saw through the hyoid and (3rd) to cut transversely through the mucous membrane. Attached to the entire length of the body and greater horns is the thyro-hyoid membrane. Oddly, the attachment is along the upper border of the body—not the lower—and the posterior aspect is free, smooth and in contact with a bursa.

Development and Ossification. The hyoid bone is one of the structures developed from the 6 paired cartilages of the branchial (pharyngeal) arches.

Each 1st cartilage (Meckel's) is converted into the incus, malleus, spheno-mandibular ligament, and one half of the body of the mandible.

Each 2nd cartilage (Reichert's) is converted into the stapes, styloid process of the temporal bone, stylo-hyoid ligament, lesser horn of the hyoid, and upper part of the body of the hyoid.

The dorsal halves of the 3rd, 4th, 5th and 6th cartilages are resorbed. The ventral halves of the 3rd become the greater horns and lower part of the body of the hyoid; the ventral halves of the 4th and 5th become the thyroid cartilage; the ventral halves of the 6th become the arytenoid cartilages and (?) the cricoid cartilage.

The body and the greater horns begin to ossify independently about the time of birth, and remain united by synchondroses until middle life, when synostosis occurs. The lesser horns articulate by synovial joints with the junction of the body and greater horns, and are partly

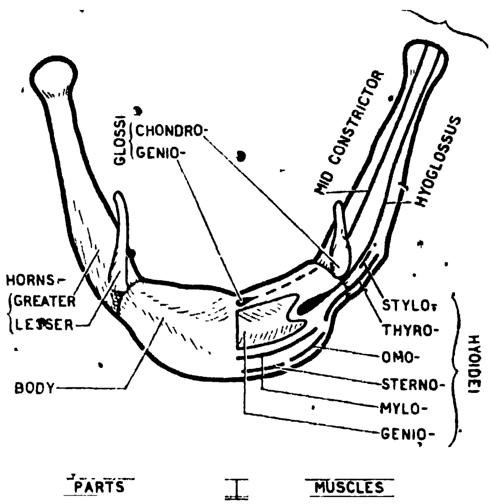


Fig. 795. Hyoid bone—antero-superior aspect.

cartilaginous at middle life; synostosis may occur.

Variations. The upper part of the stylo-hyoid ligament may ossify, that is, the styloid process may be unduly long and be a lateral relation of the tonsil bed. The lower part may ossify, that is, the lesser horn may be unduly long (as normally in many mammals).

Muscle Attachments (*fig. 795*).

Fibrous Attachments are: the thyro-hyoid membrane, lateral thyro-hyoid ligaments, thyro-epiglottic ligament, the deep fascia of the neck and the septum of the tongue.

THE SKULL AT BIRTH

The teeth of the new born child are rudimentary and unerupted the child can suck but cannot chew. Accordingly, the facial or masticatory portion of the skull is very small, being about $\frac{1}{7}$ the size of the cranium or brain pan (in the adult it is $\frac{1}{2}$ the size); the ramus of the mandible is almost in line with the body; the mandibular (articular) fossa is very shallow (*fig* 780); the air sinuses, which enlarge as the teeth erupt, are rudimentary; and the nasal cavities are small. The orbits are nearly circular There being no mastoid process, the stylo-mastoid foramen, through which

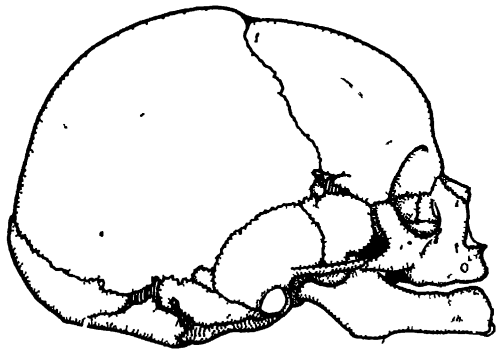


FIG 796 The skull at birth lateral aspect

the facial nerve emerges, is exposed The tympanic bone being but a ring, the ear drum is exposed. At the sites where ossification began in the frontal and parietal bones, there are eminences which are almost conical. Ossification not having reached the 4 angles of the parietal bone, the skull is still membranous at these areas; that is, there is a fontanelle at each angle (*fig.* 623). There is also a median fontanelle (sagittal fontanelle) in the interparietal suture, and another (metopic fontanelle) in the interfrontal or metopic suture.

The bones of the skull are thin, easily bent and, having no diploe, consist of a single plate. The occipital bone is in 4 pieces (*fig.* 773), the sphenoid is in 3 *fig* 646); the temporal is in 3 (*fig.* 780-*A*); the ethmoid is in 3; and the frontal bone and the mandible are each in two halves

THE BONES OF THE PECTORAL GIRDLE: A REVIEW

The clavicle is one of the two bones of the pectoral girdle; the scapula is the other

The Clavicle

General. In *type* the clavicle or collar bone is a long bone, and accordingly it has a shaft and two ends. It is *situated* at the antero-superior part of the thorax and there *articulates* with the sternum and 1st costal cartilage medially and with the acromion (and coracoid process) laterally. It is *palpable* from end to end; and by palpation it is readily determined (1) that the skin is freely movable over its entire length This is due to the interposition of the Platysma; it is therefore subcutaneous or, better, *subplatysmal*; (2) that in *shape* its medial part is convex forwards, its lateral part concave forwards; and (3) that when it is in correct *orientation* it lies nearly horizontally with the lateral end directed laterally and backwards; but, when the Trapezius, which suspends the lateral end, is vigorous, this end is slightly raised (as when the shoulders are shrugged). Its *function* is to act as a strut holding the scapula and therefore the upper limb laterally, backwards, and slightly upwards. As a result, the limb hangs behind the line of gravity and by its weight helps in the maintenance of the erect posture. When the clavicle is fractured, the shoulder falls medially, forwards, and slightly downwards, as might be expected. Animals such as the dog, ox and horse that use their forelimbs merely for support and

locomotion (i.e., for forward and backward motions) have either no clavicles or only rudimentary ones; but primates, rodents, guineapigs and bats that employ them for grasping, climbing, burrowing, or flying (i.e., for side to side motion as well) have clavicles. To *identify* the side to which a detached clavicle belongs, so hold it (a) that the flattened part is lateral, (b) that the aspect with rough markings at both ends is inferior, and (c) that the forward convexity is medial and the forward concavity lateral.

Particular. The clavicle has two functionally distinct parts—one lateral to the tip of the coracoid process, the other medial. The lateral part is flattened and forms $\frac{1}{4}$–$\frac{1}{3}$ of the bone; the medial part is prismatic, being triangular on cross-section, and forms $\frac{2}{3}$–$\frac{3}{4}$. The flattened part affords anchorage for the scapula; the prismatic part plays the role of a long bone.

THE FLATTENED LATERAL $\frac{1}{4}$ is compressed from above downwards and is united to the scapula both terminally and inferiorly, thus: (1) *Terminally*—there is a small, oval *articular facet* for the acromion of the scapula, so bevelled that in cases of dislocation the acromion is driven under the clavicle. The articular end is not enlarged like the ends of long bones in general, so the articulation depends for security upon the conoid and trapezoid portions of the coraco-clavicular ligament. (2) *Inferiorly*—these unite the coracoid process of the scapula to the clavicle and are responsible for the following markings: a tubercle, the *conoid tubercle*, which is placed below the posterior border of the bone at the junction of the flattened and prismatic parts, and a rough line, the *trapezoid ridge*, which extends diagonally across the inferior surface from the conoid tubercle to the anterior end of the articular facet.

The Trapezius is partly inserted into the posterior border of the flattened part of the bone and into the adjacent part of the upper surface; the Deltoid partly arises from the anterior border of the flattened part of the bone and from the adjacent part of the upper surface.

THE PRISMATIC MEDIAL $\frac{3}{4}$ is triangular on cross-section like a typical long bone, and accordingly has 3 surfaces separated by 3 borders. The *posterior surface*, continuous with the posterior border of the flattened lateral quarter, is concave,

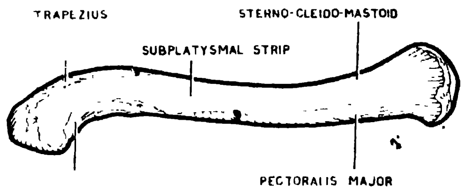


FIG. 797. Clavicle—antero-superior aspect.

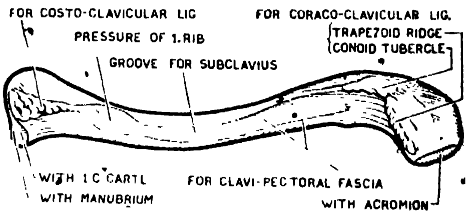


FIG. 798. Clavicle—postero-inferior aspect.

nearly vertical, and perfectly smooth and so protects the subclavian vessels and the brachial plexus which pass behind it. A nutrient foramen opens on to this surface and by its direction indicates the sternal end to be the more actively growing one.

The *anterior surface*, continuous with the upper surface of the flattened part, faces antero-superiorly. Attached to its medial inch and a half in line with the insertion of the Trapezius is the clavicular head of the Sterno-cleido-mastoid; and arising from its whole length in line with the origin of the Deltoid is the clavicular head of the Pectoralis Major—an interval of an inch or less, representing

the base of the delto-pectoral triangle, intervening. Between these 4 muscles lies the subplatysmal linear strip of the clavicle (*fig. 57*).

The *inferior surface*, continuous with the inferior surface of the flattened part, extends from the conoid tubercle to the medial end where there is a rough, half-inch-long depression (sometimes tubercular) for the costo-clavicular ligament. The area between these points is fusiform, smooth, and gives insertion to the Subclavius. The sharp lines bounding it in front and behind (= anterior and inferior borders) give attachment to the clavi-pectoral fascia (*fig. 61*).

The inferior aspect of the clavicle, then, is mainly for ligamentous attachments; the superior (or antero-superior) is subplatysmal and palpable between 4 muscles; the posterior protects the great vessels and nerves entering the upper limb, and it also can readily be palpated, provided the Trapezius and Sternomastoid are relaxed as when leaning heavily on the arms of a chair.

The three borders need not trouble us.

THE MEDIAL END of the bone is enlarged and triangular, its 3 margins corresponding to the 3 surfaces of the neighbouring part of the bone. Of its 3 angles, the superior rises above the manubrium and thereby adds to the depth of the supra-sternal notch; the posterior projects far back postero-inferiorly; the anterior is nondescript. The end of the bone is covered with articular cartilage, and this extends on to the inferior margin; it is, however, separated from its socket, formed by the sternum and first costal cartilage, by a diagonally set articular disc. Crossing in front of this end of the bone is the flattened sternal head of the Sternomastoid. Crossing behind it are the carotid and subclavian arteries (or innominate artery), the vagus nerve, and the internal jugular vein; but these are separated from the bone by the Sternothyroid and Sterno-hyoid, the former gaining part origin from the clavicle.

VARIATIONS. The clavicle varies more in shape than most other long bones. It is peculiar in having no medullary cavity. The right clavicle, though stronger than the left, is usually shorter. It may be perforated by one of the supraclavicular nerves (*fig. 59*).

OSSIFICATION. The clavicle is the first bone in the body to start to ossify, beginning during the 5th foetal week in membrane from two centres which are placed close together and which soon fuse. One represents the Trapezius-Deltoid end, the other the Sternomastoid-Pectoralis Major end. The two ends pass through a cartilaginous phase. A secondary centre appears at the sternal end about the 20th year and forms a scale-like epiphysis which fuses a few years later. An even smaller scale may be present at the acromial end.

The Scapula

General. The scapula is in *type* a flat bone, and in *shape* it is triangular. It therefore possesses 2 surfaces, 3 borders, and 3 angles. From the bone there project 2 processes (a) the coracoid process, and (b) the spine, which terminates laterally in the acromion; so, the scapula may legitimately be called irregular. It is *situated* behind the thorax where it partly covers 50 per cent of the 12 ribs, namely the 2nd–7th inclusive. Its *functions* are to give attachment to muscles, to form the socket of the shoulder joint, and by its free mobility to enhance the movements of the shoulder joint. All this it can do because its only bony connection with the trunk is through the clavicle. Its *articulations* are with the humerus at the glenoid cavity and with

the clavicle at the acromion. To *identify* the side to which a loose scapula belongs, place the spine posteriorly, the glenoid cavity laterally, and the acromion above the glenoid cavity. The cavity will then face the side to which the bone belongs.

Orientation (i.e., position in space): Since the scapula is applied to the upper part of the barrel-shaped thorax, its inferior angle lies behind the plane of the glenoid cavity, therefore the lateral (axillary) border is directed obliquely downwards and backwards as well as downwards and medially. The glenoid cavity faces laterally and slightly upwards and forwards.

Palpable parts. As the fingers run laterally along the subcutaneous strip on the clavicle, they cross the acromio-clavicular joint and pass on to the acromion. The tip of this flat plate lies in front of the acromio-clavicular joint. The tip, lateral border, angle, and posterior border of the acromion are not readily felt when the subject is carrying a weight in his hand, nor when his hand is merely hanging by his side, because in both cases the Deltoid is contracted. When, however, the arms are resting on the arms of a chair they are easily defined, because the Deltoid is then relaxed. The acromion is continued medially into the crest (posterior border) of the spine of the scapula, and both are subcutaneous. The inferior angle of the scapula can be grasped and the fingers passed between it and the chest wall when the subject's arm hangs by his side, but not when he stretches it in front of him, because the Serratus Anterior and Rhomboideus Major are then contracted. The medial (vertebral) border, which ascends from the inferior angle to the superior angle, can be palpated when the limb hangs by the side. The lateral (axillary) border can be palpated vaguely when the muscles are relaxed. The tip of the coracoid process is readily felt on pressing laterally one inch below the clavicle in the delto-pectoral triangle.

Particular. ANGLES. The *lateral angle* is truncated and enlarged to form an articular socket for the head of the humerus. Because the socket is shallow it is called the *glenoid cavity* (Gk. glene = shallow). Its anterior margin is grooved for the Subscapularis tendon; this helps to give it a pear-shaped appearance. The coracoid process, which rises above it, represents the stalk of the pear. In the quadruped mammal the cavity faces the ground and rests upon the head of the humerus; in erect man the scapula is thrust backwards by the clavicle, so the cavity faces laterally—making side to side contact with the humerus—but with a slight upward and forward tilt. The *inferior angle* is thick and rounded and gives attachment to 3 strong muscles (*fig.* 85). The *superior angle* is relatively thin and acute.

BORDERS. The *superior border* inclines laterally and downwards from the superior angle, where the Levator Scapulae is inserted, to the upper end of the glenoid cavity, where the long head of the Biceps arises from the *supraglenoid tubercle*. This border, not being subjected to stress or strain and not giving attachment to muscles - save the delicate Omohyoid—is thin and sharp. Laterally it becomes abruptly deeper, the scapular notch, which is bridged by a ligamentous band, the suprascapular ligament, which converts the notch into a foramen. Between the notch and the supraglenoid tubercle the border is, so to speak, drawn out to form the *coracoid process.* The *medial* (vertebral) *border* is arched and is thicker than the superior one, because it affords insertion to the 2nd layer of muscles of the back, namely, the Rhomboid Minor at the apex of the spine, the Levator Scapulae between the

apex and the superior angle, and the Rhomboid Major between the apex and the inferior angle. The *lateral* (axillary) *border* is thick and smooth. It extends from the inferior angle upwards, laterally, and forwards to the glenoid cavity. At its upper end it has a rough, triangular impression, the *infraglenoid tubercle*, for the long head of the Triceps

SURFACES. The *costal* (ventral) *surface* is monopolised by the Serratus Anterior and Subscapularis. Thus converging fibres of the Serratus pass to raised triangular areas at the superior and inferior angles, the inferior being the larger; diverging fibres pass to a line along the medial border which connects these triangles. The Subscapularis arises by fleshy fibres from the remainder of this surface except near the glenoid cavity. It also arises from 4 fibrous septa which create sharp lines that run from the medial border obliquely upwards and laterally towards the glenoid cavity. A smooth *strengthening bar*, running close to the lateral border, connects the glenoid cavity to the inferior angle (*fig. 86*) Between this bar and the Serratus insertion the surface is concave, the *subscapular fossa*, the concavity being deepest at the level of the glenoid cavity.

The *dorsal surface* (dorsum scapulae) is slightly arched from above downwards and near the lateral border it is corrugated longitudinally. It is divided by a triangular plate of bone, the *spine*, into a smaller, deep *supraspinous fossa* and a larger, shallow *infraspinous fossa*. The *apex* of the spine lies at the medial border of the bone and presents a smooth, triangular area across which aponeurotic fibres of the Trapezius play. The base or *lateral border* of the spine lies a finger's breadth from the midpoint of the pos-

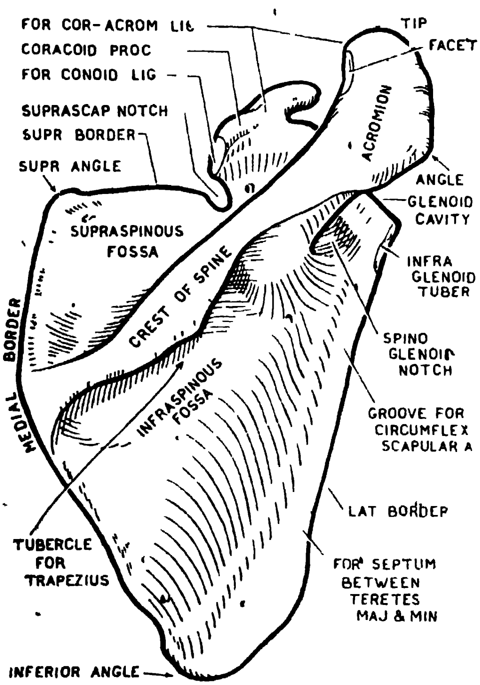


FIG. 799. Scapula – posterior aspect

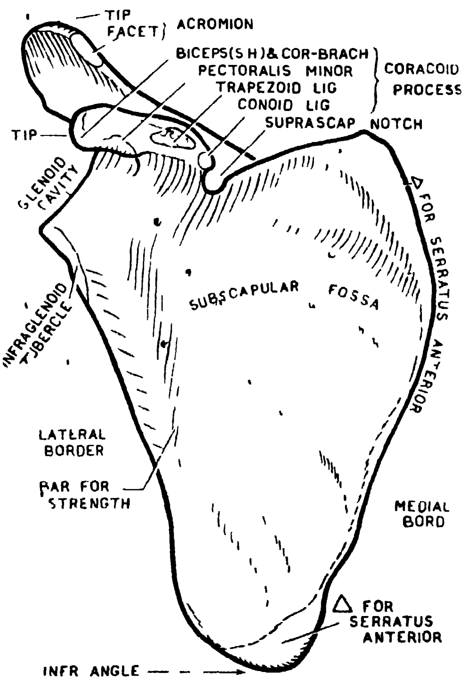


FIG. 800. Scapula—anterior aspect.

terior margin of the glenoid cavity. It is very stout and rounded and forms the medial border of the *spino-glenoid notch* through which the infraspinous branches of the suprascapular vessels and nerve pass from the superior to the inferior fossa. The *anterior border* is attached to the dorsum scapulae. The posterior border or *crest* is broad and flat, and has an upper and a lower sharp lip with a subcutaneous strip between them. The lower is for the Deltoid throughout. The lowest fibres of the Trapezius converge on the lower lip superficial to the Deltoid, and there create a downwardly directed *tubercle.* The upper lip lateral to the tubercle is also for the Trapezius.

THE ACROMION (Gk. akros = a point; omos = the shoulder; cf. acropolis, acromegaly). The spine of the scapula is drawn out laterally into a flat, stout, triangular plate the *acromion,* which overlies the glenoid cavity. It is greatly strengthened by the lateral border of the spine which fades away on its under surface. Due to this it can withstand the lateral thrust of the clavicle, the upward pull of the Trapezius, the downward pull of the Deltoid, and impacts from the humerus below. The upper, subcutaneous surface (as you may determine on yourself by palpation) is subcutaneous and faces postero-superiorly. The *lateral border* of the acromion meets the lower lip of the spine at a right angle, the *acromial angle,* readily located with two fingers. This border of the acromion gives origin to the Deltoid and possesses four tubercles for the attachment of septa that descend into the Deltoid (*fig. 83*). It is the *medial border* that troubles the student. This has an oval, *articular facet* for the clavicle; behind this the Trapezius is attached, in front the Deltoid; and the *tip* gives attachment to the apex of the coraco-acromial ligament under cover of the Deltoid.

THE CORACOID PROCESS (Gk. korax = a crow) shaped like a bent finger, has 2 parts, a vertical and a horizontal. The *vertical part* is the upward continuation of the most lateral part of the superior border of the scapula. It is smooth and flattened from before backwards. The *horizontal part* is rounded and is directed laterally, forwards, and downwards. Its tip is rough for the common tendon of the Biceps (short head) and Coracobrachialis; the anterior half of the medial border is marked for the tendon of the Pectoralis Minor, which occasionally crosses the upper surface (*fig. 166*), so only the posterior half of the upper surface is marked for the trapezoid ligament; a tubercle at the junction of the vertical and horizontal parts is for the conoid ligament, and also for the suprascapular ligament; the lateral border is marked throughout its length for the base of the coraco-acromial ligament; and approximately in line with the Pectoralis Minor the coraco-humeral ligament arises from this border.

MUSCLE ATTACHMENTS. Levator Scapulae and Rhomboidei to the whole length of the vertebral border; long heads of the Biceps and Triceps to the supra- and infra-glenoid tubercles, the Biceps also gaining attachment to the posterior margin of the glenoid cavity (*fig. 84*); Serratus Anterior and Subscapularis monopolise the entire costal surface; Spinati and Teretes monopolise the entire dorsal surface; Trapezius and Deltoid are attached to opposite lips of the crest of the spine and to opposite borders of the acromion; Omohyoid to the upper border beside the notch; Pectoralis Minor, Coraco-brachialis and Biceps (short head) to the coracoid process; Latissimus Dorsi may receive a few fibres from the inferior

angle. *Ligamentous attachments:* In addition to the capsular ligaments of the shoulder and acromio-clavicular joints there are 4 scapular ligaments; and all 4 are attached to the coracoid process. They are: the coraco-clavicular (conoid and trapezoid), coraco-acromial, coraco-humeral and suprascapular.

MEDULLARY FORAMINA are small and numerous; a large one occurs on the dorsum just below the spine, and another large one about the corresponding point on the costal surface.

STRUCTURE. The bone is thick and strong between the tip of the coracoid and the inferior angle; the acromion also is strong (*fig. 86*) but the body of the bone is thin, translucent, and devoid of cancellous tissue.

OSSIFICATION. The primary centre appears at the 8th foetal week. Secondary centres: for the coracoid in the 1st year, and subcoracoid, including the upper end of the glenoid cavity, in the 10th year; these fuse with the scapula during the 15th year. About puberty two centres appear in the acromion and others in the medial border and inferior angle; all of these fuse with the main mass about the 20th year (*fig. 78*).

ANASTOMOSES around the scapula (*fig. 75*).

VARIATIONS. The terminal *epiphysis* (metaphysis) of the acromion commonly fails to unite; the failure is usually bilateral; the epiphyseal line passing transversely through the hinder part of the oval, articular facet or just behind it (*fig. 78*). The portion of the *medial border* of the scapula below the level of the spine may be convex, straight, or concave. There are indications that bearers of the convex type are more resistant to disease, longer lived, and more intelligent than bearers of the other two types (Graves). The *supraclavicular ligament* may be ossified.

BONES OF THE CARPUS—IN SOME DETAIL

The Scaphoid Bone (Gk. skaphe = a boat).

The hollowed-out interior of the boat articulates with the side of the head of the capitate, and faces medially. Above this and also facing medially, a narrow, flat, crescentic surface for the lunate represents the stern of the boat. The smooth, rounded, exterior of the boat (it has no keel) is extensive, articulates with the radius, and faces supero-laterally. The prow, called the *tubercle*, lies infero-laterally at the front of the bone. The fo'c'lse (the distal surface) is convex and oval for the trapezium and trapezoid. Posteriorly, laterally and anteriorly there are non-articular areas, the anterior one being concave. Only through these areas can blood vessels supply the bone.

SURFACE RELATIONS. Distally, the tubercle of the scaphoid is prominent and palpable behind the point where the Flexor Carpi Radialis tendon intersects the lowest skin crease at the front of the wrist (*fig. 115*). Proximally, the scaphoid extends a finger's breadth above the skin crease—in fact, up to the prominent, palpable, crest-like anterior border of the lower articular surface of the radius. Laterally, it is palpable in the anatomical snuff-box, especially during adduction of the hand.

The Lunate Bone lies behind the mid-point of the most distal skin crease at the front of the wrist (*fig. 123*). It is semilunar or crescentic. The concavity faces distally, and with the concavity of the scaphoid forms a socket for the head of the capitate. The convexity faces proximally, articulates with the radius, and corresponds in shape and size to the

radial surface of the scaphoid (*fig. 131*). Laterally there is a narrow, flat crescent for the scaphoid. The medial surface is flat and square for the triquetrum. Between the triquetral and capitate surfaces there is an antero-posterior articular strip for the apex of the hamate. The non-articular, anterior surface is much wider than the posterior.

The Os Triquetrum (L. = three cornered, triangular) is cuneiform. The base is flat, square, and faces laterally for the lunate. The apex points medially. The distal surface is sinuous for the hamate. The anterior surface is flat, rough and has a large, round (commonly raised) isolated facet for the pisiform. The postero-superior surface is convex and rough, save for a small facet—the end of an oval—for the articular disc of the wrist joint on full adduction (*figs. 119, 122*).

The Pisiform Bone (L. pisum = a pea) is larger than the sesamoid bones of the big toe. It has only one facet and that is for the triquetrum. The facet is large and flat (or slightly concave) and on the posterior surface. It does not reach the most distal part of this surface. The lateral surface, beside which runs the ulnar nerve, is flatter than the medial one.

The other surfaces are rounded. The pisiform is crossed by the most distal skin crease at the wrist and the Flexor Carpi Ulnaris descends to it. On clenching and relaxing the fist the pisiform can be felt moving up and down. When the wrist is flexed and limp the pisiform can be moved from side to side.

The Trapezium (Gk. trapeza = a table) (greater multangular) has distally a saddle-shaped facet for metacarpal 1, but this facet has a lateral tilt because the thumb is not in line with the fingers. The anterior, lateral and posterior surfaces are rough; on the anterior surface there is a vertical groove for the Flexor Carpi Radialis tendon. On each side of the groove is a vertical ridge for the flexor retinaculum; the lateral is the more prominent and is directed towards the hook of the hamate. The medial surface is a concave half-oval facet for the trapezoid; between this and the saddle, and in line with the vertical groove, is the small facet for metacarpal 2. The proximal surface is a concave half-oval facet for the scaphoid.

SURFACE RELATIONS The ridge is continuous with the tubercle of the scaphoid and can be felt distal to the skin crease at the wrist. The trapezium is also palpable in the snuff-box at the base of metacarpal 1.

The Trapezoid Bone (Gk. trapeza = a table; eidos = like). Next to the pisiform this is the smallest of the carpal bones. The posterior non-articular surface is much larger than the anterior one. The medial surface is an oblong facet, concave antero-posteriorly for the capitate. The lateral surface is a convex half-oval facet for the trapezium. The proximal surface is a concave half-oval facet for the scaphoid. The distal surface fits like a wedge into the groove on the base of metacarpal 2.

The Capitate Bone (L. caput = a head) has at the proximal end a rounded head for the socket formed by the lunate and scaphoid, so this articular surface extends well on to the lateral aspect. Its posterior non-articular surface is flattish, and is broader than the more rounded anterior one. The base (inferior surface) is flat for metacarpal 3, and has a linear strip laterally for metacarpal 2, and a small facet postero-medially for metacarpal 4. The medial surface is flat and resembles a judge's head and wig, the head being rough for the powerful interosseous ligament that joins the

hamate to the capitate; the wig or posterior margin is articular. The lateral surface includes part of the head, as mentioned; distally it is convex antero-posteriorly for the trapezoid.

The Hamate Bone (L. hamatum = hooked) is a wedge-shaped bone with a hook. The anterior and posterior surfaces are rough and non-articular; the hook curves laterally from the anterior surface and points towards the ridge on the trapezium, for both give attachment to the flexor retinaculum, (*fig. 131*). The distal surface or base has two concave facets which allow metacarpals 5 and 4 to flex and extend; the medial one is somewhat triangular (or quadrate), the lateral one is quadrate (cf. the cuboid bone of the foot). The lateral surface is flat and partly articular for the capitate and partly rough for the strong interosseous ligament which unites it to the capitate. The supero-medial surface is sinuous for the triquetrum. The hook is crossed by the ulnar nerve and artery, and its lower border is grooved by the deep branches of the ulnar nerve and artery. The hook is felt as a resistant surface on pressing deeply in the palm infero-lateral to the pisiform.

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